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Surface Soil Metal and Metalloid Contamination Within the Urban Environment of Atlanta, Georgia

Lanier Henson

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by

Lanier E Henson

Under the Direction of Daniel Deocampo, PhD

ABSTRACT

Previous research from urban cities around the world have found elevated soil lead concentrations in many of the cities because of anthropogenic deposition of lead from industrial, transportation, and residential applications. Children, impoverished populations, and pregnant women all experience increased adverse health risks when exposed to land with elevated soil lead concentration. The project tested the following hypotheses concerning soil lead within the Atlanta urban environment; soil is enriched from transportation sources and deteriorating lead paint, soil lead is not sourced from the weathering of the bedrock or soil, and enrichment is heterogeneous. The hypotheses were tested through the geochemical and spatial analysis of 750 soil samples collected within the Atlanta urban environment, utilizing Xray fluorescence, inductively coupled plasma mass spectroscopy analysis, and statistical interpretation. Soil lead concentrations in the 100µm fraction ranged from 10ppm to 3029ppm, with a median value of 75ppm. Soil lead concentrations in the bulk samples were less enriched and ranged from below detection limit to 2599ppm, with a median value of 59ppm. Semivariograms of the data, illustrates poor spatial autocorrelation between samples at this sampling distance.

INDEX WORDS: Atlanta, Urban Environment, Soil, Contamination, Lead, XRF, GIS

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Lanier E. Henson

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DEDICATION

…… Thank you, Mom and Dad! Nothing I have done would have been possible without your continued love and support!

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LIST OF ABBREVIATIONS

XRF – Xray Fluorescence

BLL – Blood Lead Level

EBLL – Elevated Blood Lead Level

EPA – Environmental Protection Agency

PPM – Parts per Million

CDC – Center for Disease Control

REC – Recognized Environmental Contaminant

PCA – Principal Component Analysis

1 INTRODUCTION

Soil lead contamination is a common problem and major health risk to children within many urban environments, but little work has been done to understand the severity or extent of the enrichment within Atlanta Georgia. Soils lead concentrations within the continental United States typically range from 10 to 50 mg/kg or ppm (USGS, 2006). Atlanta is located within the Piedmont province of Georgia and neither the bedrock nor soil have no major sources of native lead. The lack of lead bearing minerals within the Georgia Piedmont implies that an enrichment of lead is a result of anthropogenic inputs. Widespread use of lead in domestic and industrial applications throughout history have led to dramatically increased concentrations of lead within the soil of urban environments worldwide. The purpose of the study is to determine within Atlanta, Georgia the severity of lead contamination within surface soils and establish the basis for understanding the current background levels within urban environments.

Lead has been integrated into numerous industrial and residential products because of its density, malleability, low cost, and ease of extraction. Some of the few applications have been as an additive in paints to increase the shine of white paints, and as an anti-knocking agent in leaded gasoline. In many cases substitutes have been found to replace the use of lead, but unfortunately there any many applications of lead still in practice throughout the developed world, even though we have learned of the dangers posed by lead exposure. These dangers are especially risky when children are being exposed. There has been a great deal of work identifying the connection between the enrichment of soil lead and elevated blood lead levels (EBLLs) of a population. Fine lead particles can become re-suspended and be transferred great distances from the original point of deposition (Filippelli, 2005). As lead particles are

transported, lead from the soil, air, and deteriorating lead-based paint can result in lead loading of household dust as it is tracked inside (Laidlaw, 2008). Residential lead loading increases as a function of traffic density suggesting the lead additives in gasoline is the major contributor to lead contaminated house dust (Mielke, 1998). Lead is highly immobile within the environment, can have very low solubility, and is not biodegradable resulting in the contamination remaining within the soil for thousands of years (Liggans and Nriagu,1998; Zhu, 2001; Abrahams, 2002). With over 84,000 homes within the counties comprising Atlanta built before 1950, the risk of residential homes containing lead contaminated dust at harmful levels to the children is great (CDC, 2015).

Children living with in an urban environment have higher blood-lead levels (BLLs) than children living in suburban or rural areas (Lanphere, 1998). This is because of chronic exposure to low levels of lead over their lifetime. Anthropogenic lead partitions into highly bioavailable carbonate, iron, and manganese hydroxide soil fractions due to surface charges (Filippelli, 2005). When populations are exposed to lead through ingestion not all the lead is absorbed or retained through the digestive tract in the same quantity or rate. Urban soils and dust enriched in lead can be absorbed within the body at up to three times the rate of lead from paint because of smaller particle sizes and speciation of lead (Mielke, 1998). In addition to leaded paint, urban soils, and lead loaded house dust, the U.S. Environmental Protection Agency (EPA) considers lead in drinking water as the major sources of EBLL's (Mielke, 1998).

The portions of Cobb county, Fulton county, and Dekalb county within interstate 285 comprise the Atlanta urban environment. In 2015, the Center for Disease Control performed their annual surveillance of EBLLs for every county in Georgia and found children with

EBLLs between 5 and 9μg/dL in all three counties. Fulton and Cobb County had a combined 31 individual children with EBLLs above the threshold of 10μg/dL of the 11,052 children tested (CDC, 2015). The accumulation within the various compartments of the urban environment results in increased exposure to the local populations, with the greatest risk being towards young children and impoverished communities. The partitioning of lead between the soil, water, and atmosphere is a result of both the original source of the lead and current environmental factors specific to each location within the city: oxidation state, soil pH, water pH, and concentration of competing ions.

To achieve the objective of determining the severity of lead contamination within surface soils and establish the basis for understanding the current background levels within urban environments of Atlanta, eight hundred discrete soil samples were randomly collected using interstate 285 as the boundary of the urban environment. Soil samples were analyzed for lead and other trace metal concentrations through the application of X-ray fluorescence and Inductively coupled plasma mass spectroscopy. The concentration of lead will be spatially compared to determine if any relationships are present with population density, bedrock geology, or soil type. Matrix of inter-correlation and principal component analysis testing was used to determine any correlation between these metals for differentiating trends in shared sources (Laidlaw, 2008; Deocampo, 2012). Kriging was be performed within ArcGIS (10.4.1) to generate a prediction map of surface soil lead concentration between sample locations.

2 BACKGROUND

2.1 Atlanta, Georgia

The city of Atlanta and Georgia's state capital has been a hub for business and industry since the 1800s. Founded in 1847, Atlanta was a railroad transit stop to the West. Since then Atlanta has become an important city for the entire region, serving as a major convention center since the 1980's. With the rapid growth, many of the old neighborhoods and building have been demolished or refurbished to accommodate the population increase. According to the 2010 Census data, Atlanta is the third fastest growing city in the country. The United States Environmental Protection Agency has addressed dangerous levels of soil contamination at three local smelting locations: Atlanta Steel Company, Miller Metal #87, and Miller Metal #86 previously located in the center of the urban environment. Atlanta Steel was located along Bishop Street in what is now called West Midtown. Miller Metal #86 was located just North of the connector in Downtown Atlanta along Interstate 85, while Miller #87 was located in the modern neighborhood of Old Forth Ward, East of Downtown. Since 1974, the City of Atlanta was divided into twenty-five Neighborhood Planning Units (NPUs), which are citizen advisory councils that make recommendations to the Mayor and City Council on zoning, land use, and other planning issues. Twenty-two of these NPUs are located within the study region are mapped with sample locations in Figure 13. Because all the samples do not fall within the NPUs, the 2010 census tracts were mapped with the sample locations in Figure 14.

2.2 Study Region Geology and Soils

2.2.1 The Georgia Piedmont Ecoregion

The Georgia Piedmont ecoregion is the largest of the five within Georgia spanning 17,253 square miles, or 29% of the State (Edwards, 2013). In addition, the Piedmont contains over half of the state population and the State Capitol, serving as a regional transportation hub. Figure 1 illustrates the ecoregions of Georgia including the Piedmont, as mapped by the USGS in 1990. The Piedmont is further divided into the inner and outer piedmont with the most significant difference being the topographic relief of the Outer Piedmont being much less. The Brevard fault is the divide between the two sub-regions and acts as a hydraulic control for the Chattahoochee from the NE to the SW. The soils in the inner Piedmont are thinner than those of Outer Piedmont, especially along the ridges were soil thickness is between 3 and 6 feet (Edwards, 2013). Atlanta and its urban environment lay mostly within the outer Piedmont ecoregion. There are localized regions of ultramafic bedrock through outer Piedmont, but predominant bedrock is granitic gneiss and mica schists (Edwards, 2013). This crystalline bedrock restricts the weathering of the rivers resulting in floodplains hundreds of feet wide, which deposit fine alluvial deposits during storm events. The soils of the Piedmont are acidic and nutrient-poor on average. The texture of the Piedmont soils ranges from sandy to loamy depending on local topography and hydrology.

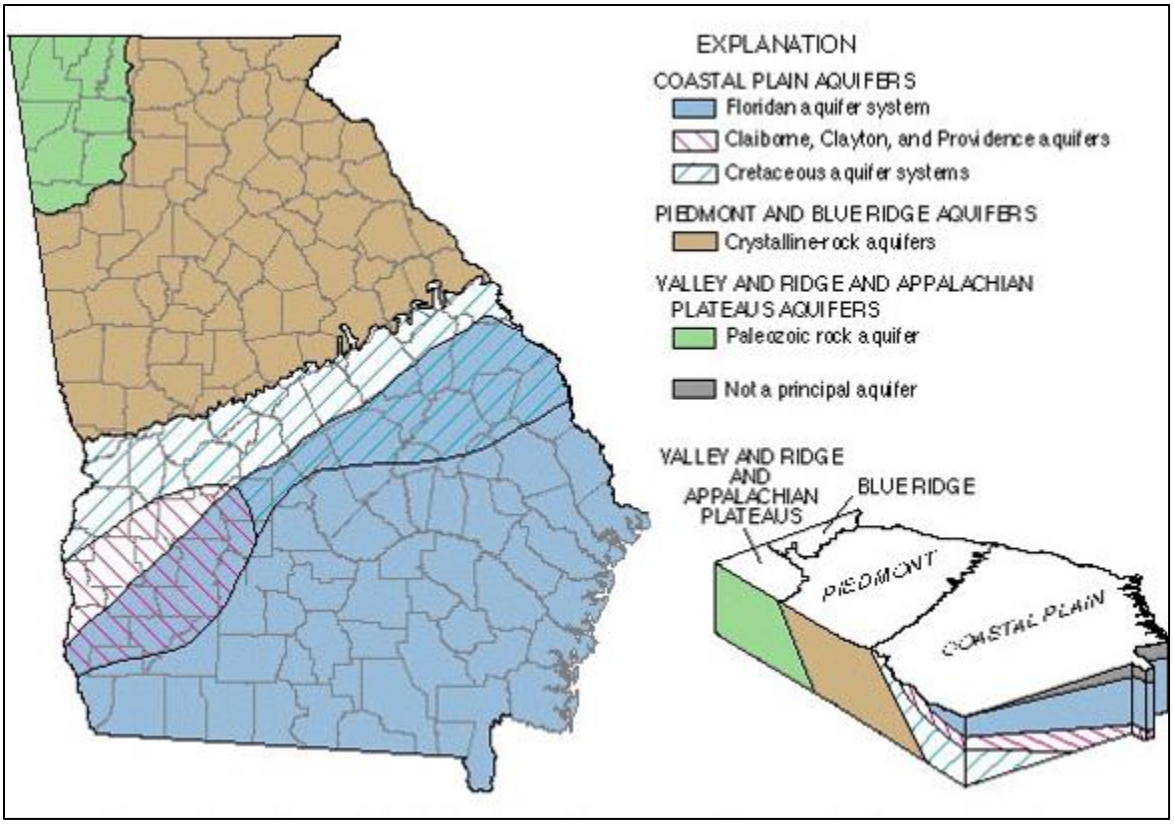

Figure 1: Map of Georgia Ecoregions and Primary Aquifers adapted from (USGS, 1997)

2.2.2 Bedrock of the Georgia Piedmont

Atlanta is located within the Piedmont region of Georgia between the Blue Ridge Mountains and the Upper Coastal Plains. Bedrock formation range in age from Paleozoic to Precambrian. Since the late Precambrian, a thick layer of sedimentary rock covered the basement rock of the southern extent of the Piedmont. Several periods of volcanism and igneous intrusions have variably metamorphosed the bedrock throughout the region. Figure 2 illustrates the predominant rock type of the region are various forms of gneiss, mica schists, quartzite, mylonite, and ultramafic intrusions (Lawton and others, 1976; USGS, 1997).

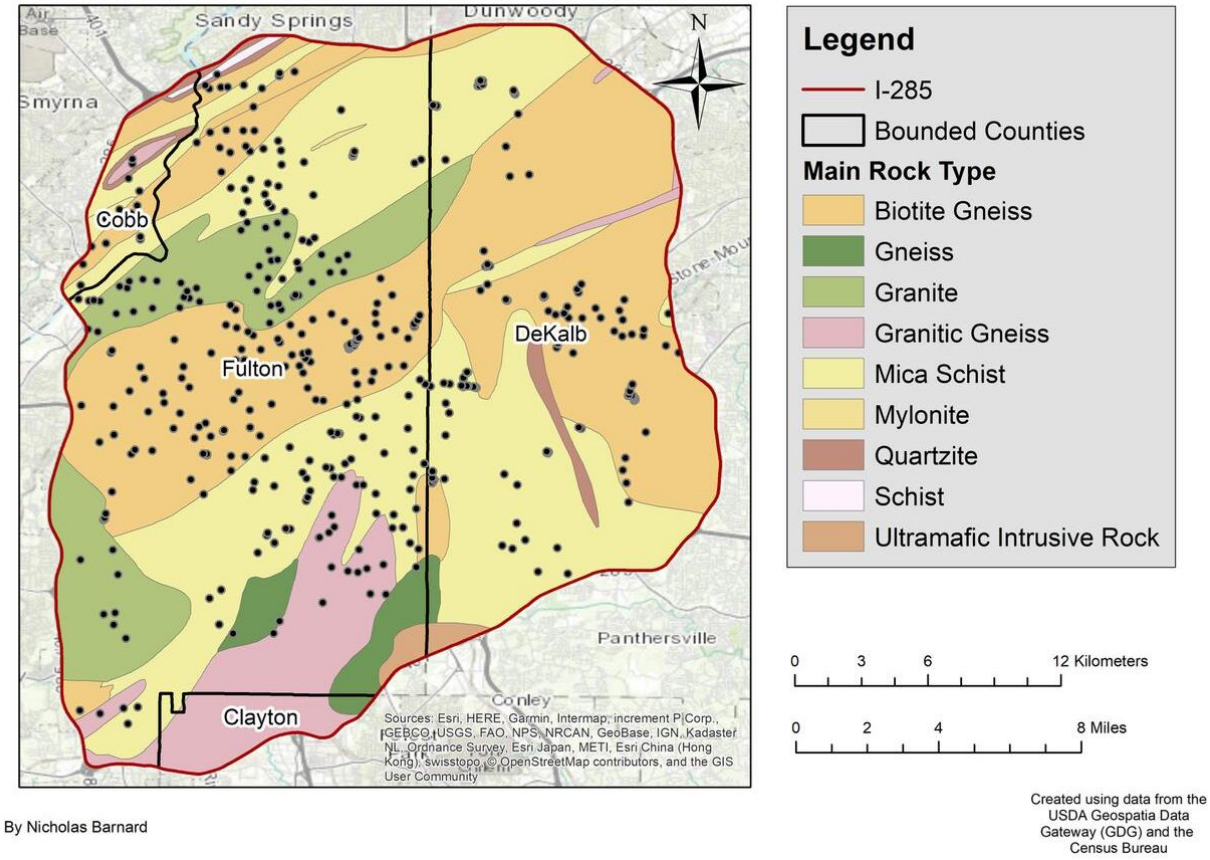

Figure 2: Sample Locations within Underlying Bedrock Geology (USGS, 1997)

2.2.3 Soils of the Georgia Piedmont

The soils within the Georgia Piedmont area primarily characterized as an ultisol with a typically pH around 4.7. The primary mineralogy of ultisol soils are kaolin, quartz, Vermiculite, and iron oxides in decreasing abundance (USGS, 2006). The mineralogy of the soil is dependent on the bedrock material in natural settings, but within the urban environment the mineralogy will be extremely variable and a function of mixing of source material through development. The native soils of the Piedmont are weathered from various forms of gneiss, mica schists, quartzite, mylonite, ultramafic intrusions, and ultra-mafic dikes. As the bedrock is exposed to the atmosphere, chemical weathering occurs heterogeneously. Heterogeneous

weathering produces the variation within the soil during formation. For example, the granitic gneiss weathers heterogeneously because of varying degrees of metamorphism, folding, and mineralogy differences in layers. The feldspars within these rocks weathered to kaolinite. Amphibole and biotite weather to iron oxides through hydrolysis and oxidation giving the distinct red color of Georgia Soil (Gore and Witherspoon, 2008). The high content of clay minerals and iron oxides create conditions optimal for lead sorption because of the surfaces charges which develop in the material (Zhu, 2001; Wong, 2003). The ridges of quartzite through Atlanta however, weather more homogeneously to sandy soil, rich in angular quartz grains. The mean background soil-lead concentrations according to a survey of geogenic soils performed by the USEPA in Georgia, is 13.2 ppm with a standard deviation of 8.9 ppm (EPA, 2010).

Ultisols naturally adsorb significant amounts of lead to the surfaces of the colloidal fraction of particles, less than 1 micron in diameter (Emmanuel, 2002). The colloidal fraction consists of clay grains, organic material, and oxides. Ultisols are naturally low in organic material, characteristically around 1.9% by weight, but the soil of the Georgia Piedmont should be expected to have even less. During the mid-1800's poor agricultural practice led to the erosion of the top 7.7" in some areas, to as much as multiple meters in others (Edwards, 2013). The ultra-mafic veins will develop weathering fronts along the edges of Fe-oxides and clay minerals. Within the river channels and along the floodplains alluvial deposits gather from material eroded from more northern regions. The deposits weathered from the Precambrian sedimentary rock are mainly saprolite, rich in clay minerals rich in silicon, aluminum, as well as iron oxides and resistant minerals such as quartz (Edwards, 2013).

2.2.4 USDA Soil Types Located within Atlanta's Urban Environment

As illustrated below in figure 3, the Atlanta Urban Environment is composed of 5 primary soil types: Georgeville, Mecklenburg-Iredell-Eonn-Davidson, Urban Developed Soil, Urban Madison-Davidson, and Urban-Madison-Cecil (USDA, 2005). The soil type data was generated utilizing the clipping tool in ArcGIS on the 2006 USDA soil survey of the State of Georgia to the study site boundary. The following soil description is defined by the USDA soil series metadata included within the 2005 Georgia Soil Survey (USDA, 2005). Georgeville soils within Atlanta are well drained, yellow to brown and are classified as a silty loam. They typically are composed of moderate organic content, and thick well-defined clay dominated B-horizons between 24" and 48" in depth (GEORGEVILLE Series, 2007). The Mecklenburg-Iredell-Eonn-Davidson soils are reddish brown and well drain within Atlanta. The soils are typically a loam with moderate granular structures and range from strongly to moderately acidic (IREDELL Series, 2016). The urban soils are not well drained as an entirety. The Madison Davidson urban soils are classified as gravely sandy loams, yellowish brown. The Madison series forms from the continued weathering of saprolite formed from felsic to intermediate high-grade metamorphic and igneous rocks of Piedmont. These soils are strongly acid due to this weathering process as well. The Madison-Davidson series will be redder in color than the Madison-Cecil which is typically more yellow. The Madison-Davidson is a result of cultivation and development of the soil, while the Madison Cecil is a product being forested over time (DAVIDSON Series, 1999; MADISON Series, 2002).

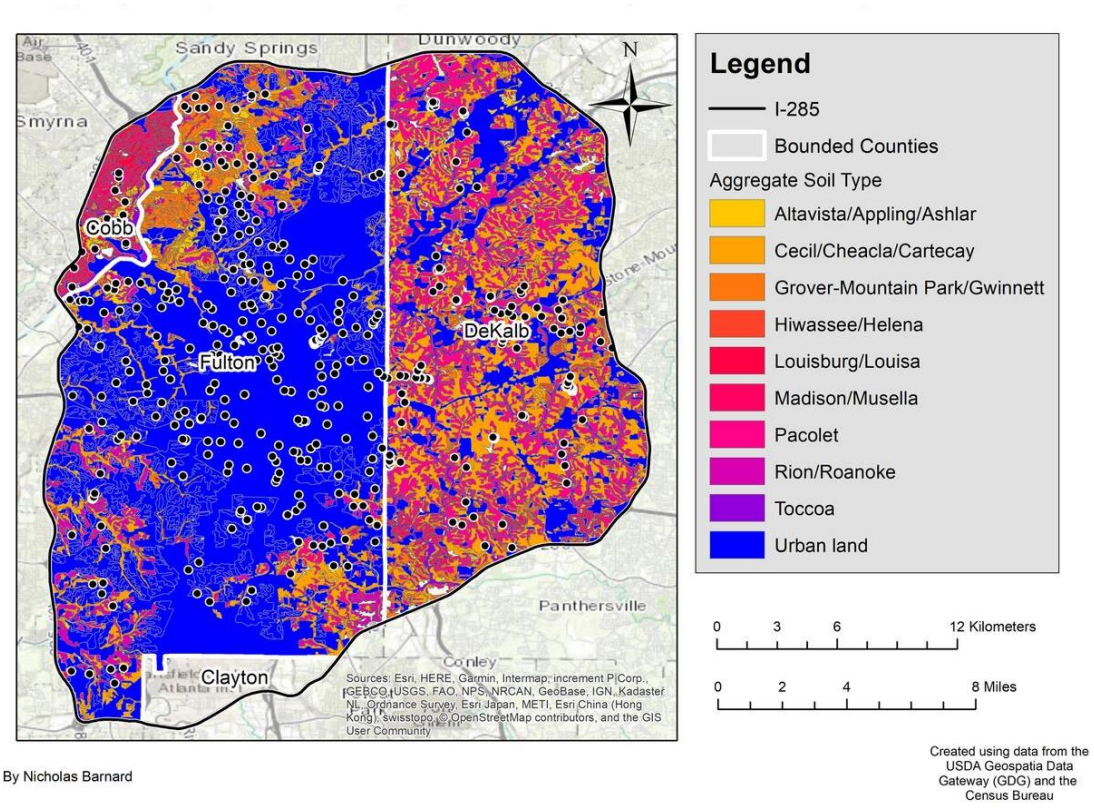

Figure 3: Sample Locations within USDA Soil Survey Soil Types

2.2.5 Urbanization of the Georgia Piedmont

The composition of soils within the urban environment show a great deal of variance from native soils with the same bedrock. The variation of mineral and chemical composition is caused by the increase of non-native materials being integrated or deposited on the native soils. The variability of lead in surface soils in the urban environment exhibits poorly spatially autocorrelation and an operational scale between tens to hundreds of meters. Additionally, the variability of lead between the dust found within transportation infrastructures, and the soil is even greater (Biasioli, 2006; Deocampo, 2012). The high amount of variability of soil-lead is a result of the multiple sources and the nature of anthropogenic dispersion (Callender, 2000; Biasioli, 2006). Anthropogenic dispersion of lead particles generates declining concentrations

with increased distance from point sources (Filippelli, 2015). Fine grain lead particles can travel for several kilometers through the atmosphere before settling to the surfaces of building and the ground resulting in low levels of enrichment across the entire region. The fine grain particles are often sourced from the combustion of TCE or industrial stack emissions, but mixing can make identifying a specific source nearly impossible. Anthropogenic lead particles typically have lower isotopic 206/207 ratios than natural lead particles making it possible to distinguish native from anthropogenic, but not specific sources. Isotopic ratios of lead do not change through application or biologic reactions making the source distinctive in ratio if mixing has not occurred (Rabinowitz, 1995). The accumulation of the deposited fine particle lead and lead from deteriorating paint are the main inputs to the chronic surface soil contamination in many cities worldwide (Filippelli, 2015; Laidlaw, 2017).

Metals of common sources typically accumulate in the soils together such as the presence of Cd and Pb together as trace elements of some fertilizers, which, after continuous use, may result in increased levels within the soil (Jones, 1981). Figure 4 illustrates the variation of the metals in sorption behavior in relation the ferrihydrite, a common constituent of Georgia soil. Lead is shown to be completely fixed at pH over 5 and completely mobilized at a pH below 3. The most common soil contaminants in order of abundance are Pb, Cr, As, Zn, Cd, Cu, and Hg (USEPA, 1996). Some urban gardens have discovered twice the level of lead contamination in urban soils compared to agricultural soils (Schwarz and Pickett, 1987). In the Georgia Piedmont there is an extensive risk of contamination because of the amount of development in the region; half of the state population. Figure 5 maps the land use and land cover within the study region. The population growth is nearly double that of the rest of the country (Edwards, 2013; Kundell, 2017).

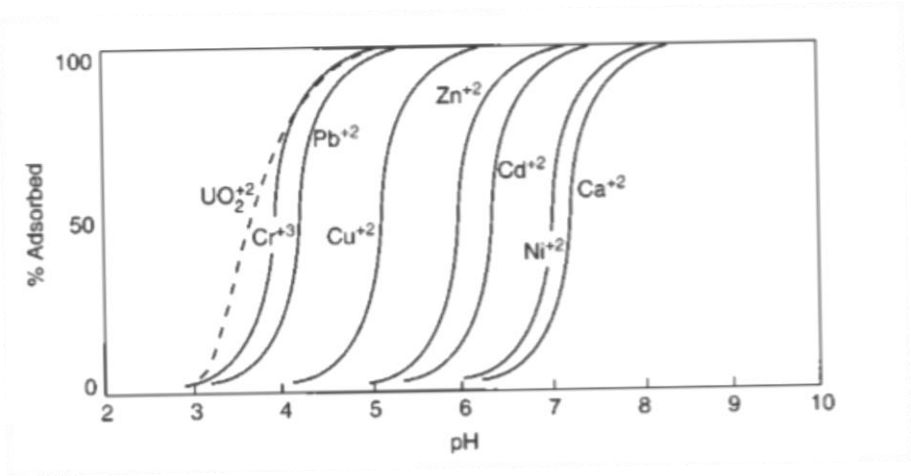

Figure 4: Absorption of Metal Cations onto Ferrihydrite as function of pH (Dzombak and Morel, 1990)

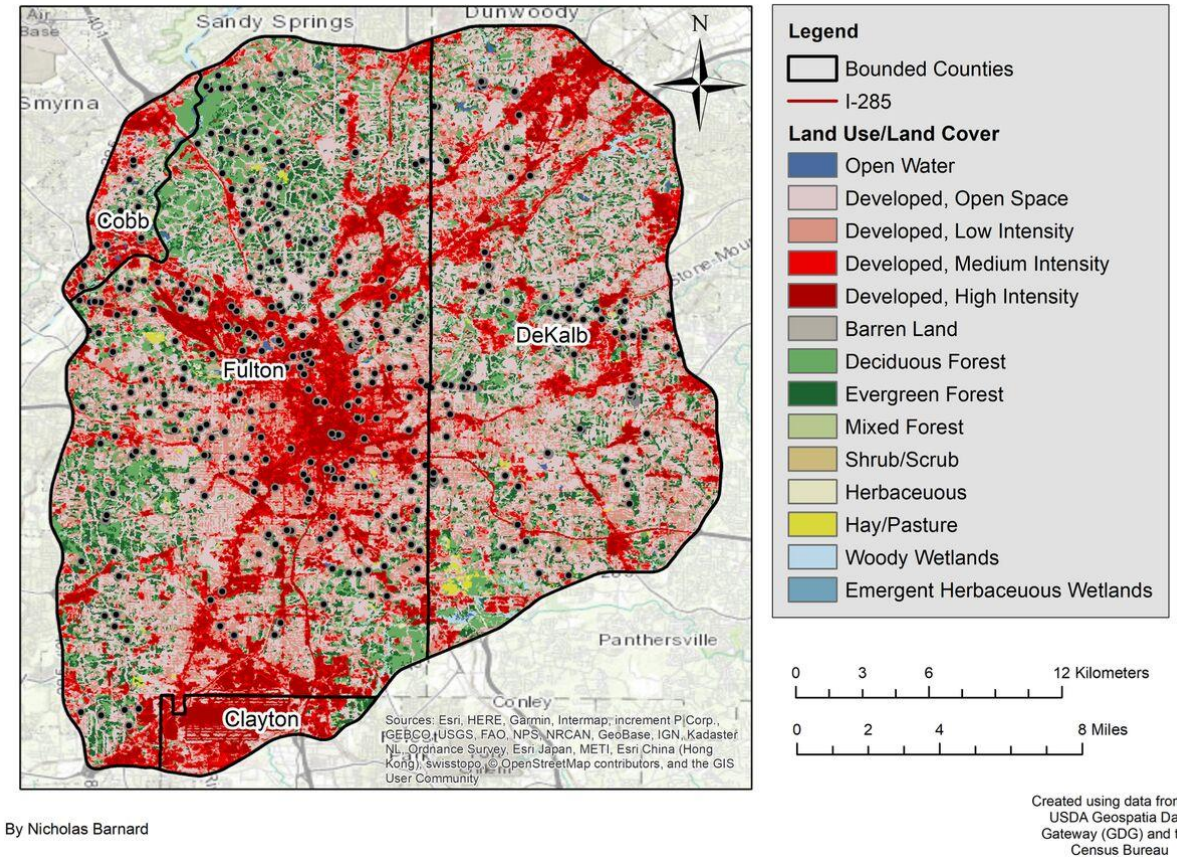

Figure 5: Sample Locations against Land Use and Land Cover

2.2.6 Mobility of Lead in Ultisols

Once the lead is integrated into the crystalline lattice of a mineral, it becomes less soluble and in turn less bioavailable to plants and people. The pH of the environment, oxidation state, the concentration of lead, and concentration and type of competing ions will determine the mineral speciation. Ultisols typically have a pH around 4.7 but considering the amount of urbanization of Piedmont, the pH is probably lower, with high amounts of variability near developed lands. Lead will sorb to the surfaces and edges of colloidal material in soils: clay minerals, soil organic matter, and on Fe- oxide surfaces. Initial adsorption can occur in minutes or hours with long reactions taking years or days to form (Smith, 1999). In soils, the primary control for lead mobility is the pH of the environments and the point of zero charge, pZc, of the surfaces (EPA, 1999).

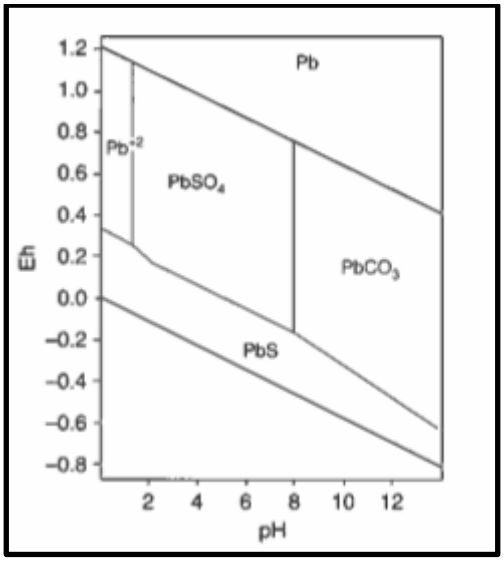

Figure 6: Eh-pH Diagram of Lead (Dzombak and Morel, 1990)

Figure 6, the Eh-pH diagram of lead illustrate lead is not soluble at pH found within soils (pH 3-6), but below pH 2 it may become dissolved in aqueous solution as ionic Pb(II) (Erdem, 2005). Galena is stable over a wide range of pH and will serve as the solid-state control within reducing soil environments. Above a pH of 7 lead carbonate, Cerussite, is stable and precipitates from solution, serving as a control for dissolved lead. Anglesite is another common lead mineral in soils between pH of 3 to 4 (Dzombak and Morel, 1990). The colloidal content of a soil is going to be the ultimate control for the lead sorption capacity and the strength of the bonds formed. The preferential adsorption to the colloidal fractions will be determined by the specific CEC, pH, and oxidation state of the soil, which will express highly spatial variable and variability with depth. In Figure 7, Emmanuel (2002) illustrated the partitioning of lead in the various colloidal constituents as a function of depth in two Mediterranean soils. Through surface bonds and adsorption, the affinity for the lead was oxides > organic material > silicate minerals, and the role of carbonates will be minimal in acidic soils (Emmanuel, 2002; Kundell, 2017).

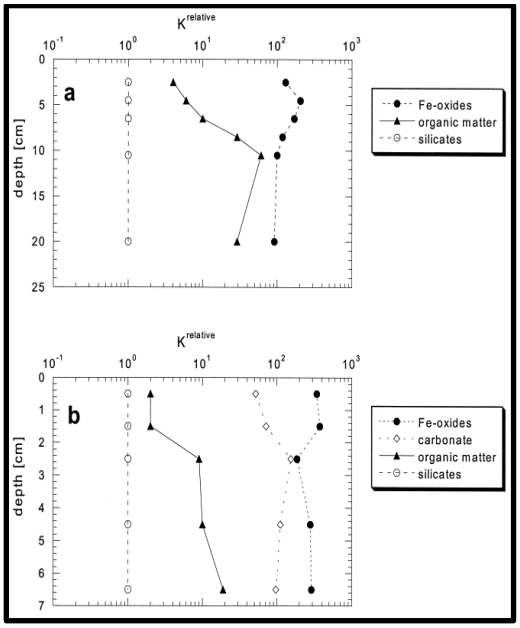

Figure 7: Concentration of Lead as Function of Depth (Emmanuel, 2002)

Clay minerals, both 1:1 and 2:1 have been applied as adsorption materials both in lab studies and in field application, showing the extremely efficient capacity of clays to immobilize lead in soils (Sipos, 2008; Jiang, 2009; Kundell,2017). The lead bond to the surface through electrostatic bonds. Due to the heterogeneous charges along the surface of many clays the sorption is not uniform across the surface. Expose hydroxyl complexes along the edges of clays, such as kaolinite, have also been known to retain lead particles (Ashman and Puri, 2006). Not all clays have the same potential to remove lead. In order of increasing affinity for lead sorption some clay minerals are as follows; kaolin > illite > montmorillonite. Vermiculite was `also seen to have a particularly high ion exchange potential for lead (Nriagu, 1996). 2:1 clay minerals have a permanent surface charge compare to 1:1 clays whose charge is variable with soil pH. The 2:1 clay also adsorb the lead differently than the 1:1 clay which binds the lead to edges and surface. 2:1 clays can substitute Pb(II) for Ca and K in the interlayer (Ashman and Puri, 2002).

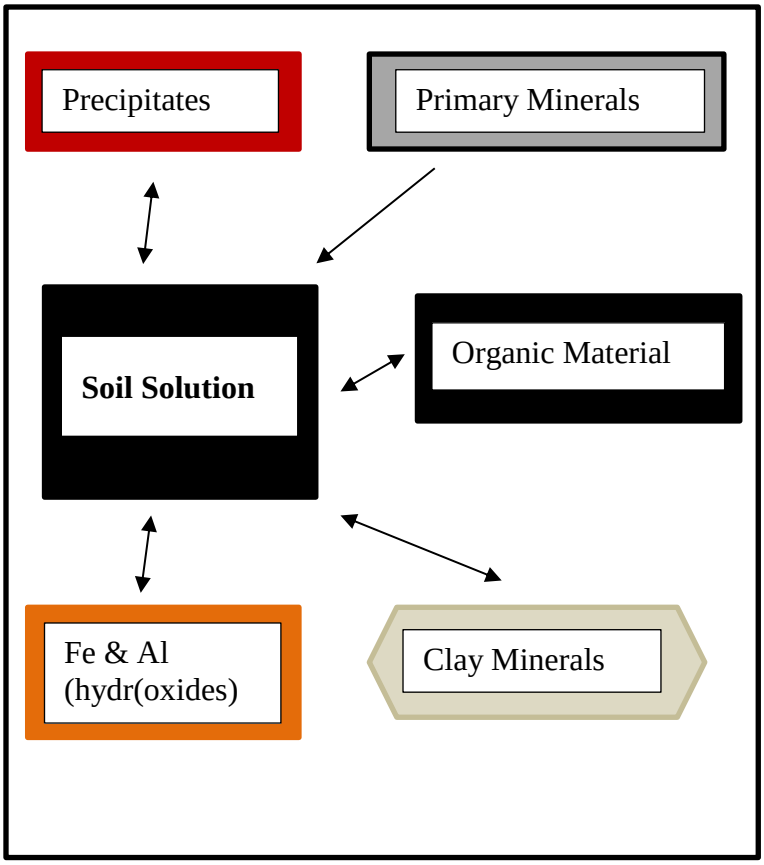

Figure 8: Sorption Sites for Lead within a Soil Solution (Ashman and Puri, 2006)

In more neutral pH settings between 6 and 7.5, oxides and hydroxides will serve as the primary sorption sites for the lead from soil (EPA, 1999; Appelo and Postma, 2005). This is also the range of acidy in which the greatest amount of sorption is seen in the soil. These oxide and hydroxide bonds are surface bonds between Pb(II) and the exposed hydroxyl complexes (Scrudato, 1974). When Fe-oxides precipitate from solution in the soil, Pb(II) has been seen incorporating into the lattice of the complex, making it less mobile than the lead adsorbed to the surface through surface bonds. In contrast, lead contained in organo-metallic complexes such as with fulvic and humic acids, are easily bioavailable to people (Ashworth and Alloway, 2008). This is also the range of acidity in which the greatest amount of sorption is seen in the soil. These oxide and hydroxide bonds are surface bonds between Pb(II) and the exposed

hydroxyl complexes (Scrudato, 1974). When Fe-oxides precipitate from solution in the soil, Pb(II) has been seen incorporating into the lattice of the complex, making it less mobile than the lead adsorbed to the surface through surface bonds.

2.3 Lead within the Urban Environment

2.3.1 Chemical Characteristics of Lead

Lead, with an atomic symbol Pb, is a heavy metal in group IV and period 6 in the periodic table. Lead's atomic number is 82, with an atomic mass of 207.2 and density of 11.4 g cm^{-3}. Lead has 3 oxidation states: 0, +2, and +4 and is classified as a chalcophile. There are four stable isotopes of lead: ^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb. Additionally, there are four heavy isotopes: ^{210}Pb, ^{211}Pb, ^{212}Pb, and ^{214}Pb. ^{204}Pb is non-radiogenic, or primordial, while ^{206}Pb, ^{207}Pb, and ^{208}Pb are radioactive decay end members of ^{232}Th, ^{235}U, and ^{238}U respectively. The heavy lead isotopes are intermediate products of the U and Th decay sequences. (Li, Zhang, Shao, and He, 2017).

Under the Berzelius-Goldschmidt classification system, a chalcophile has a low affinity for oxygen and will preferentially form covalent bonds with sulfur to form lead sulfide (Berzelius-Goldschmit, 1923). Because of this preferential bonding, the lead will mineralize and remain on or close to the surface infiltrating downward (Emmanuel, 2002). The lead components of mineral compounds such as galena, PbS, can be anthropogenic or pedogenic in origin and typically occur at concentrations less than 1000 mg kg^{-1} classifying lead as a trace metal (USDHHS, 1999; Wuana, 2011). Lead may also be found within the crystalline lattice of minerals, commonly replacing calcium through isomorphic substitution of Pb(II) because of the similar charge to radius ratios. Lead is rarely found as a metal in nature, but rather a

compound, combined with other elements. The most common mineral forms include anglesite, cerussite, crocoite, wulfenite, pyromorphite, vanadinite, and jamesonite.

2.3.2 Natural and Anthropogenic Sources of Lead

The United States Geologic Society completed a survey of surface soils and found the natural background lead concentration within surface soils of Georgia are approximately 12.3 mg/kg with a range of 2.7 to 38.7 mg/kg (USGS, 2017). The natural concentration of lead within the environment is dependent on the concentration of pedogenic lead, Urianium-238, Uranium-235, and Thorium-232 in the parent material of the soil. As these elements radioactively decay the abundance of radiogenic lead increases. Current concentrations of Pb^{206}, Pb^{207}, and Pb^{208} are 25%, 21%, and 52% respectively. The ratios of the concentrations of lead (206/204), (207/204), and (208/204) then record the source of lead, with complication occurring from mixed sources. Anthropogenic lead deposits typically have a lower 206/207 ratio than naturally sourced lead (Erel, 1998).

The atmosphere is the first recipient of contaminations containing anthropogenic lead at least 1 to 2 orders of magnitude greater than natural sources (Komarek, 2007). By the 1960s and 1970s, the introduction of alkyl lead gasoline was the largest source of anthropogenic lead in the environment, with industrial sources becoming the predominant source after most countries banned its use. The lead additive in gasoline, tetra-ethyl lead (TCE), was added to increase engine performance and reducing knocking. Lead in gasoline, was significantly more dangerous than natural forms because it can be absorbed through the skin and is released a particle less than .1 micron in diameter. These fine grain particles are easily suspended in the atmosphere as an aerosol and can be transported for kilometers before settling. (USDHHS, 1999; Laidlaw, 2017). Currently, the largest source of anthropogenic lead in our urban

environments is the deterioration of leaded paint from the peeling and flaking of chips. The paint chips are mobilized with increased pH. Lead from deteriorating paint is potentially the most dangerous to individuals because it is already concentrated around the home as the paint deteriorate or is improperly removed during remodeling (Filippelli, 2013; Laidlaw, 2017).

Through time the uses of lead have enriched lead within surface soil concentrations above background levels (Callender, 2000). Historically the largest inputs of lead were lead in house paint, tetra-ethyl lead, and industrial stack emissions (Callender, 2000; Filippelli, 2015). Leaded gasoline the United State deposited over five million metric tons across the country with the greats amounts of contamination occurring next to point sources and within cities (Filippelli, 2015). Since the mid-1970s the use lead as an additive in paints and fuels has dramatically declined making non-source points contamination from paper, plastics, ceramics, and automobile parts an increasingly important source of lead (Callender, 2000).

2.3.3 Uses of Lead

The first to begin using lead were groups in Southwestern Asia approximately 5000 years ago during their smelting process. The first significant production lead, however, began in 3000 BC throughout the Roman Empire. During this time approximately 80000 ton of Lead was being produced annually for applications in pipes, bath linings, roofs, coffins, cisterns, colored glasses, and even as a taste enhancer (Nriagu, 1996; Komarek, 2007). Figure 9 illustrates the amount of leaded gasoline and paint used within the United States as a function of time between 1910 and 2010. At the beginning of the 20th century, industrial activity and the introduction of leaded gasoline would further increase the amount of lead released into the environment. By the 1960s and 1970s, the introduction of alkyl lead gasoline was the largest

source of anthropogenic lead in the environment, with industrial sources becoming the predominant source after most countries banned its use.

Tetra-ethyl lead was the lead additive in the gasoline, now banned in the United States, added to increase engine performance and reducing knocking. This form of lead may also absorb through the skin making it significantly more dangerous than natural forms, which must be, inhaled or ingested (*USDHHS, 1999).* The mass dispersion of tetra-ethyl lead across the country from the combustion of the Tetraethyl lead (TCE) is responsible for much of the lead found in our cities today. By 1955, the US EPA reported as many as five thousand Americans dying annually from lead poisoning, which would prompt later legislation. By 1986, the use of leaded gasoline discontinued in the United States, with exception of private propeller planes, which still use TCE today.

The deterioration of leaded paint from the peeling and flaking of chips is currently the largest source of anthropogenic lead in our urban environments. Lead (II) chromate and lead(II) carbonate are the common forms of lead added to paints to increase drying speeds, durability, and resistance to moisture. These sources are potentially more dangerous to individuals because it is already concentrated around the home as the paint deteriorate or is improperly removed during remodeling.

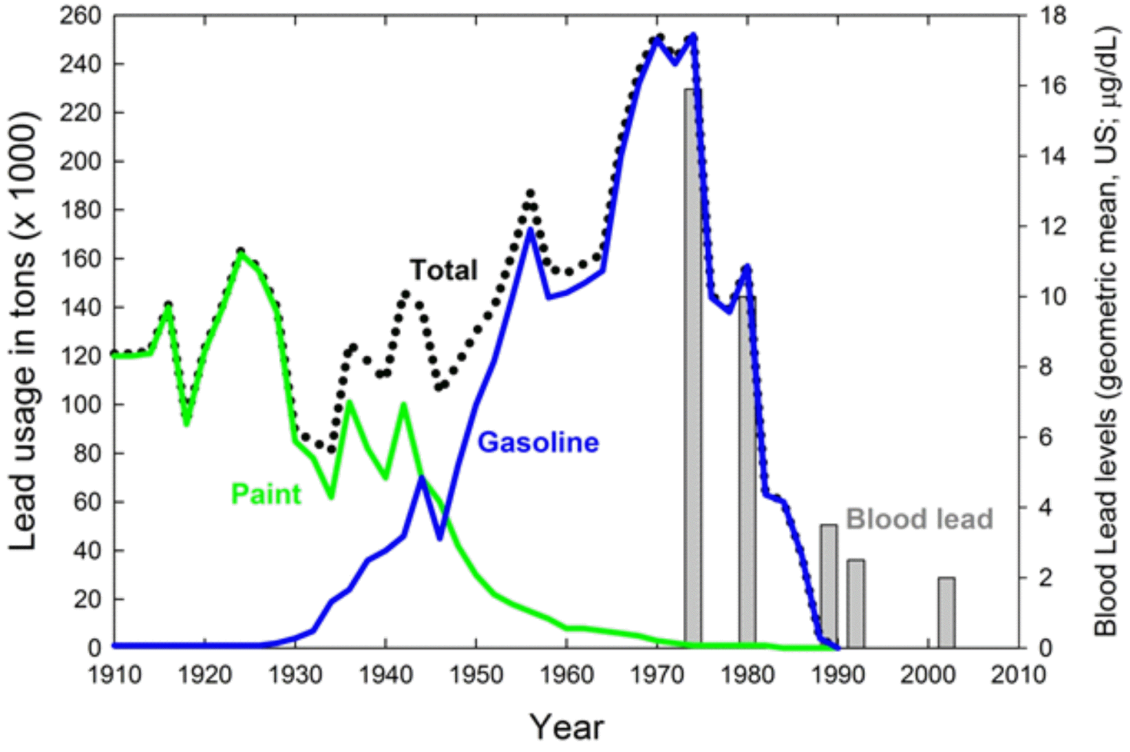

Figure 9: Leaded Gasoline and Paint Usage in the United States, 1910 to 2010 (Filippelli et al., 2005)

2.3.4 Adverse Health Effects of Elevated Blood Lead Levels

By 1955, the US EPA reported as many as five thousand Americans dying annually from lead poisoning, which prompted legislation to restrict further input into the environment. Urban soils are the ultimate sink for the anthropogenic lead resulting in elevated surface soil lead concentration and urban soils becoming the primary exposure pathway for urban populations. This is especially true for young children because increased hand to mouth behavior resulted in increased inadvertent ingestion (Filippelli et al, 2005; Laidlaw et al, 2005; Laidlaw and Filippelli, 2008; Laidlaw et al, 2008). According to the Center for Disease Control, there is no known safe Blood lead levels (BLL) but they have identified 5 µg/dL as a limit of health concern (CDC, 1991). Subsequently, the EPA has set an action limits for both industrial and residential soils at 1000ppm and 400ppm respectively. The various limits and threshold for

exposure have changed numerous times as studies identify the negative effects at increasing lower levels.

Lead is dangerous in the environment because it is both a neurotoxin and actively replaces calcium within the body. The results of lead accumulation in the body dependent on the amount of exposure and the individual's health, which usually occurs as a result of inadvertent ingestion or inhalation. The resuspension of soil lead into the atmosphere has been thoroughly studied as a major contributing source of lead to urban populations (Filippelli et al., 2005; Laidlaw et al., 2005; Laidlaw and Filippelli, 2008; Laidlaw, 2012). The ingestion occurs from particles less than 2.5 microns in diameter; penetrating the body's natural clearance mechanisms in the respiratory tract (Charlesworth, 2010).

The risk of elevated blood lead levels, (EBLLs) is especially high in children whose bodies can only remove ~32% of digested lead through either urine or feces. The developing intestines absorb the available lead which is transmitted throughout the body. Over time, the excess lead will accumulate in the brain, liver, and bones (Tsoi, 2016; USDHHS, 1999). The Pb(II) isomorphically substitutes for Ca^{+2} which results in lower IQs, developing behavioral problems and learning disabilities, as well as brittle bone disease. Children are at the greatest risk during exposure to lead contaminants because they have a thinner blood-brain barrier, making even low levels of lead exposure over extended periods much more concerning than in adults (Lidsky, 2003). As children develop, the sources of lead available to them change as well. Children 6 to 30-month old see EBLLs greater than infants 0 to 6 months due to increased hand to mouth content during development. A study of lead sources from children's incisal (Enamel) and cervical (dentine) teeth indicated changes in the source of lead through development from in *utero* to early childhood (Morrison 2013). Lead, being a neurotoxin and

easily substituting itself for Calcium and zinc in the body, is responsible for neural development retardation and the formation of behavioral problems in children exposed to elevated levels (Lidsky, 2003). Reduced intelligence, hearing impairment, and delay in female puberty are all symptoms of prolonged exposure to lead in children as well (Tsoi, 2016). Urban children are disproportionately at high risk of having EBLLs than children raised in suburban homes because the urban soils and road dust contains more elevated lead levels than rural cities (Morrison, 2013). CDC National Surveillance Data (1997- 2015) show Fulton County and Decatur having between <1% to 3% of children tested having BLL greater the 5 μg/dL, the threshold where children begin to exhibit adverse effects. Less than 1% of children tested over the threshold limit of 10 μg/dL (CDC, 2015).

In adults, increased BLL's have caused toxicity in the bone morrow, liver, kidney, and central nervous system, and in extreme cases increased systolic blood pressure and mortality. Not all adults are at equal risk of contamination from the same exposure due to physiologic differences from diets. Those exposed to lead through inhalation or ingestion while fasting or hungry absorb up to 80% of the bioavailable lead compared to as low as 2.8% in adults who had eaten (Gulson, 2008). Women who are pregnant or breastfeeding have increased risks associated to exposure due to the increased absorption of metals in the nervous system, as Ca^{+2} is usually released during this time (USDHHS 1999; Tsoi 2016).

2.3.5 Exposure Pathways

Fine lead particles can become re-suspended and be transferred great distances from the original point of deposition (Filippelli, 2005). As they are transported the lead from the soil, air, lead-based paint it can lead to dust lead loading within the residences as it is tracked inside (Laidlaw, 2008). Residential lead loading increases as a function of traffic density suggesting

the lead additives in gasoline is the major contributor to lead contaminated house dust (Mielke, 1998). Figure 10 illustrates this cycling of lead through various reservoirs within the urban environment. The proximity of the nearly 50% of the world's population living in close proximity to urban soils enriched in lead increase the risk of exposure through dermal contact, ingestion, and inhalation of particles (Abrahams, 2002; United Nations, 2014). Lead poisoning or individuals experiencing EBLLs typically are children, with exceptions being among men working in fields such as construction or the automotive industry (Elderidge, 1992).

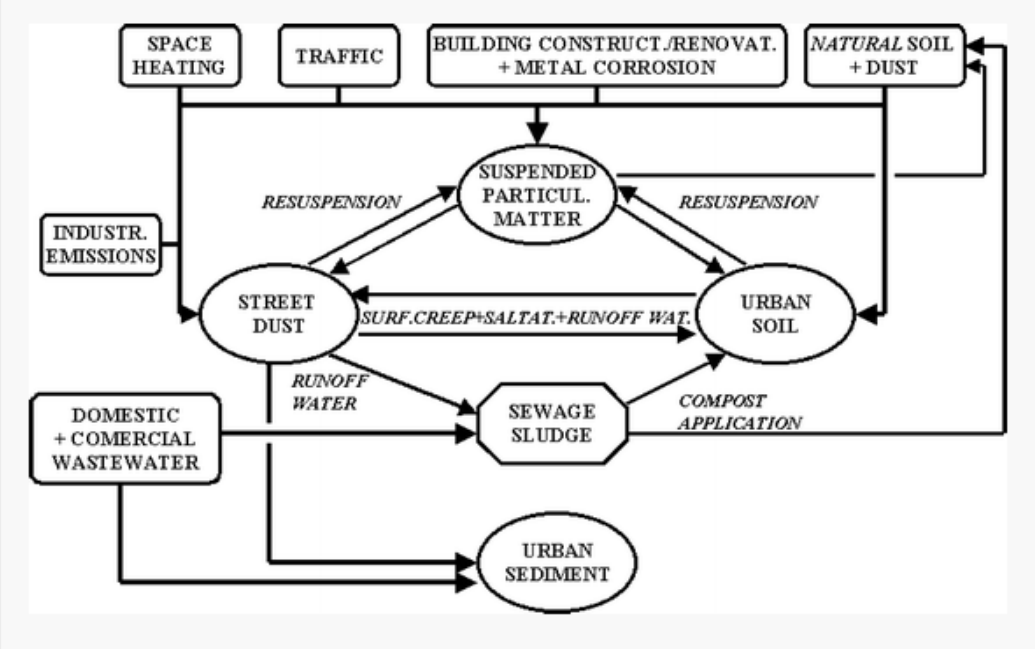

Figure 10: Distribution of Particulate Trace Elements in the Urban Environment (Charlesworth and Ordonez, 2011)

3 METHODS

3.1 Site Location

Atlanta's urban environment was selected as the study site location because the city has never had a thorough study of the surface soil lead contamination in terms of presence or extent. Some local sites within the urban center have been studied in terms of environmental compliance for real estate transactions or Superfund projects, but large studies have not been completed due to the large sprawl of the urban development. Currently, the region IV EPA office is beginning a study to determine modern background levels of the large urban centers within the Southeastern United States and this study should serve as a foundation for that work. The historic metal manufacturing industry within the city center and the housing stock's age both suggest the presence of enriched soil lead levels. In addition, the rapidly increasing population of the city in recent decades is driving the redevelopment of many of the older properties increasing the risk of suspending the soil lead to the atmosphere. Figure 12 displays the 2010 census tracts within the urban environment and the sample locations within them. Samples gathered within the city of Atlanta and the the neighborhood planning units are displayed within figure 13.

3.2 Sampling Site Selection

The area within Interstate 285 is the Urban Environment of Atlanta. The land within Interstate 285 is mixed-use including many private homes, industrial production, major traffic infrastructure, and public resources. Soil samples were collected with the urban environment within interstate 285 around Atlanta. Samples collected on both public land and private property, with the permission of the owners. Samples from public land include public parks, public schools, and sides of the roads. A 25 by 25 grid was created with interstate 285 serving

as the outer bounds of the study area. These grid cells have no geologic or geographic importance but ensure the sample locations is well distributed across the urban environment. Locations were assigned using the "create random points tool" within ArcMap 10.4 (Environmental Systems Research Institute). Sample locations were then assigned as close to the randomly assigned locations, considering ground cover and access restrictions. Samples are collected where the following criteria can be met: 1) soil is in a passive geologic setting and has not been recently disturbed 2) soil is within 3m of any major roadway, 3) soil is at least 5m from any permanent structure, and 4) areas of low vegetative coverage. Because lead, like other metals, can be absorbed through plant roots areas of high vegetation may contain less than representative amounts of lead for the area (Wang et al., 2005). Once collected, soils were stored within the Geoscience Department of Georgia State University until analysis.

3.3 Soil Sample Collection

Sample sites were assigned randomly using GIS, but while in the field individual determinations based on access and ground conditions determined if the sample location would be relocated within the proximity. The 800 sampled locations within the urban environment of Atlanta were collected using a plastic trowel to prevent any possible contamination from typical metal tools. Between samples, the trowel will be thoroughly washed using deionized water and Kim wipes. Each sample will consist of sediment for the top 5 to 8cm of soil. According to the USGS this portion of the soil profile is of greatest concern for contamination because of its proximity to those living in the area. This depth also contains large concentrations of organic material and alliminosillicates which sorb lead, preventing the migration further down the profile. At each location, photos were taken North and South of the sample location to aid in land use determinations. Land use, land cover, dominate grain size,

soil color, soil moisture, and GPS coordinates were also collected for each sample. Once removed from the ground, samples were placed in plastic bags, sealed until later preparation for analysis, and be stored at Georgia State University within the Geosciences department.

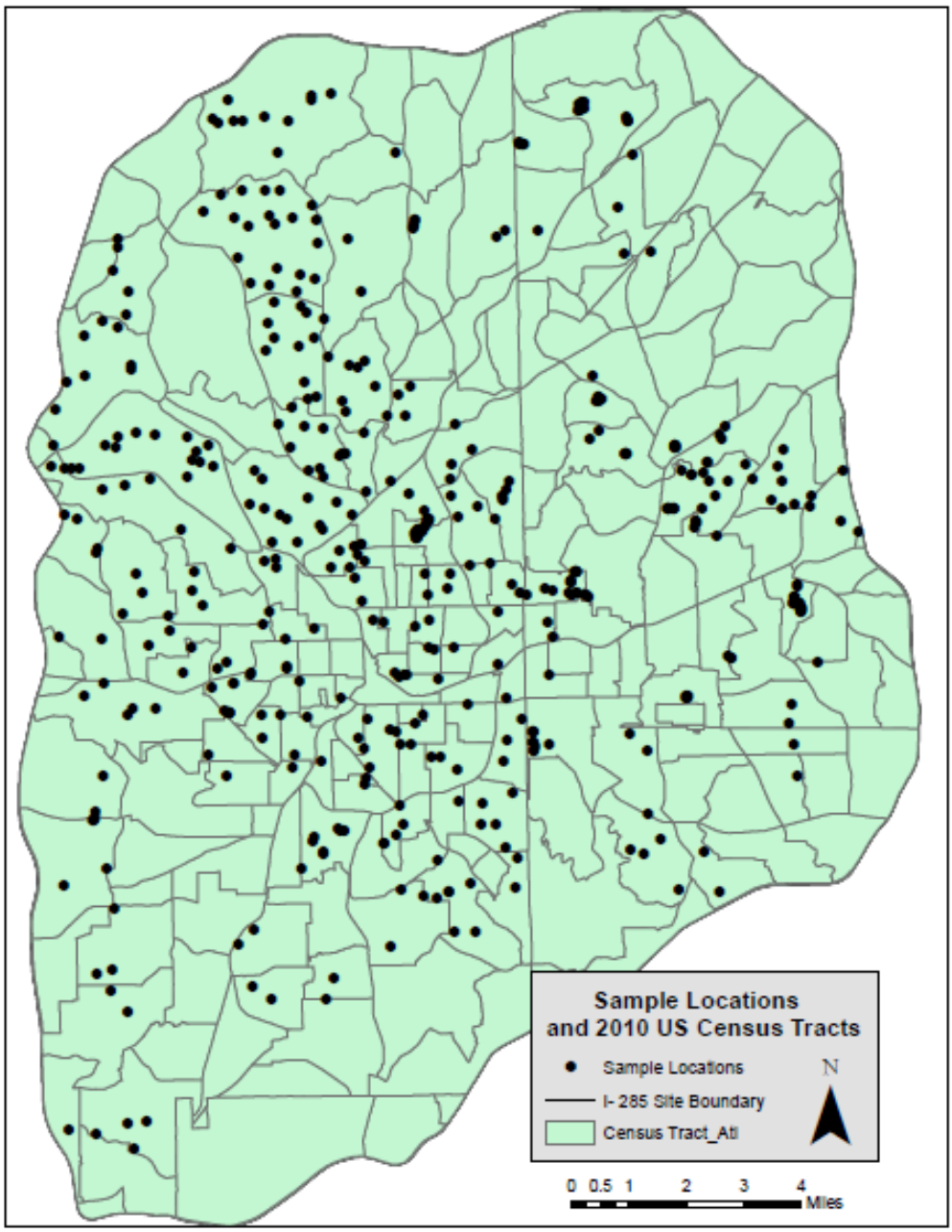

Figure 11: Sample Locations Plotted Against 2010 US Census Tracts

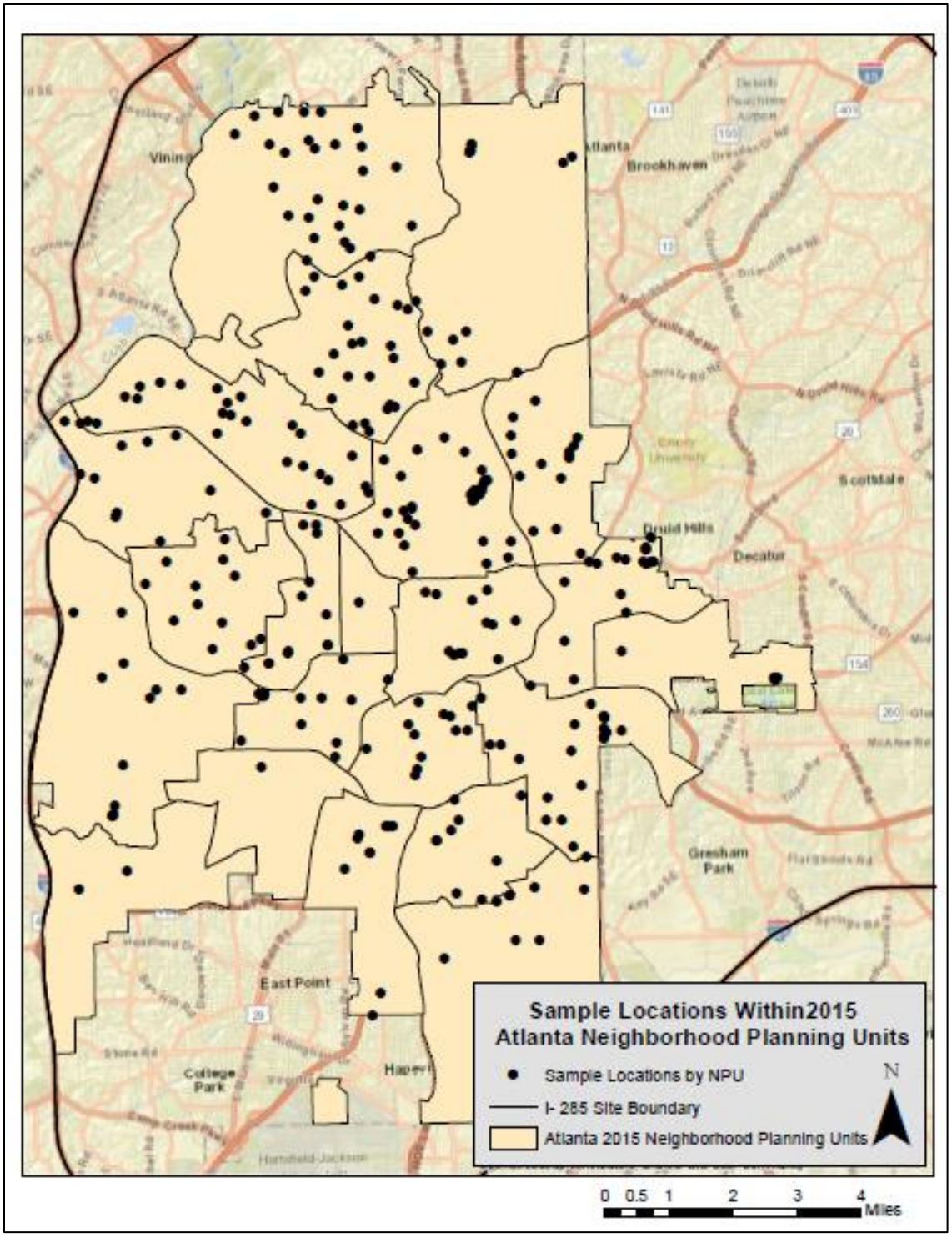

Figure 12: Sample Locations within the City of Atlanta 2015 Neighborhood Planning Units

3.4 Xray Fluorescence Analysis

Handheld, Innov-X, α–4000 x-ray fluorescence spectrometer (XRF) was used to analyze both the bulk soil samples and the 100-micron grain size portion soil samples. The instrument uses a tungsten x-ray tube and an energy-dispersive spectrometer. Bulk samples were analyzed four times per sample to account for the inherent heterogeneity of various grains within a soil. The results of the four analyses were then averaged for geospatial analysis within ArcMap. The samples that were sieved to 100-microns using a plastic screen and sieve. The fine grain samples are utilized to test the significance of the colloidal transport and create homogenized samples for more accurate results. Each of the 100-micron samples was analyzed with the XRF twice then the results averaged for statistical analysis utilizing Principal Component Analysis within SPSS.

3.5 Soil Sample Preparation for Fine Grain XRF Analysis

Each sample was placed in an oven to dry over a 24-hour period at 120 degrees Celsius. Once dried samples were sieved to 100-microns. then The geochemistry of the remaining samples will be analyzed using field portable X-Ray Fluorescence (XRF). The XRF analysis is not as sensitive as the ICP-MS but it allows many more samples to be included in the project's budget. Statistical correlations between the various metal abundances will be calculated using Principal Component Analysis within SPSS. The geospatial analysis will be calculated within ArcMap using the Geostatistical analysis toolset. Datasets from two supervised undergraduate sample collection projects, sampling North Atlanta, will be included in the fine grain geospatial analysis.

3.6 ICP-MS Sample Analysis

Replicates were created from 20 of the discrete soil sample for inductive coupled plasma mass spectroscopy (ICP-MS) at Actlabs in Toronto, Canada. Samples were selected to represent the entire range of soil lead concentrations across. By representing the entire range of values the results will serve as a quality control for the accuracy of the XRF results. Act labs will perform a 4-acid complete digestion each sample using nitric, perchloric, hydrofluoric, and hydrochloric acid. This is done to remove all portions of the soil except for the metals of concern. Inductively coupled plasma mass spectrometry is ideal soil geochemistry because of its low detection limit.

3.7 Spatial Analysis

Seven hundred and fifty discrete soil samples were collected throughout the study area between September of 2016 and December of 2017. For each location, ground cover, land use, dominant soil grain size, and the moisture content for each soil sample was recorded. Samples collected using the Survey123 app also recorded photos of the North and South cardinal directions from the sample location. The soil collection site locations were recorded using the North American Datum (1983) and were uploaded to Google Earth to generate a KML file for the Sample site. This file was then uploaded to ArcMap.

3.8 Statistical Analysis

Due to the vast number of samples, visually interpreting the data is very difficult. Statistical analysis of the individual components of each locations aid in the interpretation and presentation of the data set. The statistical analysis also is useful for the determination of the accuracy of relationships between variables. The descriptive statistics table 1, displays the mean, median, minimum, maximum, and standard deviation of lead concentrations for both

the fine grain soil analysis. This information is critical for initial review of the data but lacks the detail to understand subtle trends. Statistical Analysis was performed within SPSS and ArcMap. SPSS will be used to generate comparative box plot graphs of the descriptive statistics to visually present the trends in lead concentrations between various factors. Geostatistics tools within Arcmap were used to generate the inverse distance weighting predictive maps. For each of the predictive maps semivariograms/ covariance graphs, QQ normal plots, and histograms were generated as well.

Principal component analysis (PCA) was performed within SPSS to determine the correlation between the various factors of each sample. PCA provides the initial inspection of the eigenvalues that represent the majority of the data set variation; the proportion of cumulative variance explained by each factor. To determine the number of unique factors which are responsible for the variation within the dataset, a scree plot was first generated. The point along the curve of the scree plot where the curve most dramatically reduces its curvature indicates the number of factors to include. Varying the number of factors included determined the stability of the factor loading for the PCA. The analysis would be considered stable when factor loading value is .50 or greater since more than three variables were included (Korre, 1999).

The reproduction of the observed correlation matrix indicated that a sufficient number of factors were included (Johnson & Wichern, 1998). Poor reproduction matrix is indicators that either too few or too many factors were utilized when performing the PCA. The factors were rotated using an orthogonal varimax rotation, which accentuates high loading and diminishes the influence of low loadings (Korre, 1999).

Residual matrix displays how closely the parameter estimates of the PCA method reproduced observed correlation matrix (R). The observed correlation matrix displays the correlation between the various elements analyzed through the fine grain XRF procedure and the correlations between the lead concentrations and the various site conditions. An exact reproduction of values between the observed and the reproduction would result in a residual matrix entirely of zeros. The minimum and maximum values represent the greatest variation between the reproduced values and the observed values measured from the discrete samples collected.

4 RESULTS

4.1 X-ray Fluorescence

4.1.1 Bulk Sample Analysis

Four hundred and Ninety bulk soil samples were analyzed using a hand-held, Innov-X, α-4000 X-ray Fluorescence (XRF) spectrometer at Georgia State University (GSU). The soils samples were stored at GSU in temperature-controlled labs prior to analysis but were not sieved nor were they dried. Samples were scanned three times then averaged to account for the increased heterogeneity of the bulk samples. Fifteen of the samples analyzed had lead values above the Environmental Protection Agency's (EPA) action level of 400 ppm. The greatest concentration was 2599 ppm and the minimum concentration was 10ppm. Figure 13 is the histogram of the bulk soil lead concentrations. Nine of the highest concentrations were found in soils located within community parks and residential zones. These extreme values generate the skewed shape of figure 13. Figures 18 and 25 represents the results of inverse distance weighting of the soil lead concentrations between sample locations for both the 100-micron soil fraction and bulks soil samples. These should only be used as an initial visual aid for interpretation and not for measurement extraction because the sampling distance is greater than the autocorrelation of lead, as shown by the nuggets of figures 24 and 29. Figures 14 and 15 are visual representations of the clustering of high and low points throughout the study region and the downtown urban core of the city of Atlanta. The median concentration is 59 ppm and the mean is 144ppm. The large difference in values between the median and mean results are due to the presence of extremely high outliers within the dataset.

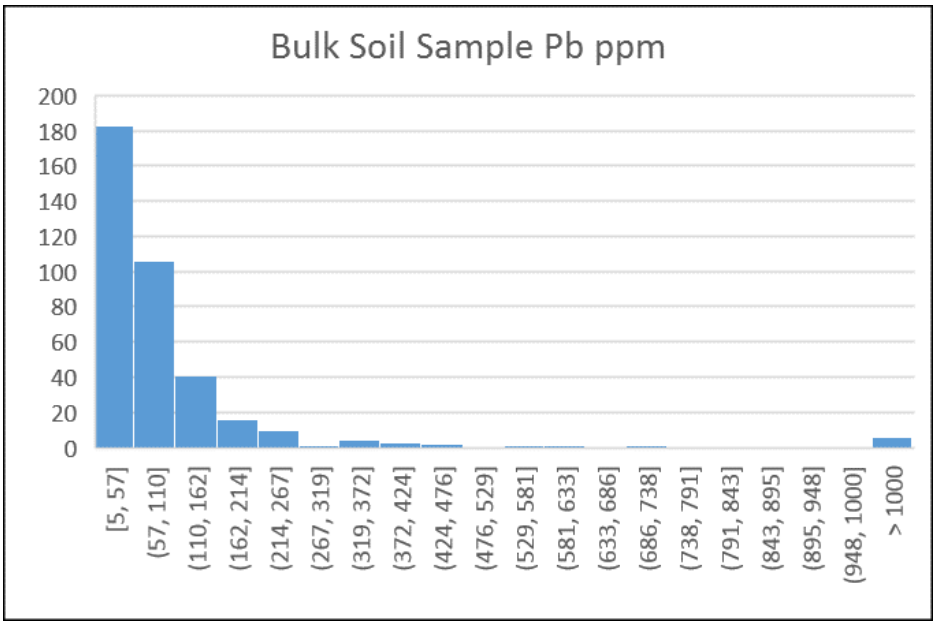

Figure 13: Histogram of Soil Lead Concentrations within the 100-Micron Fraction through Handheld XRF Analysis

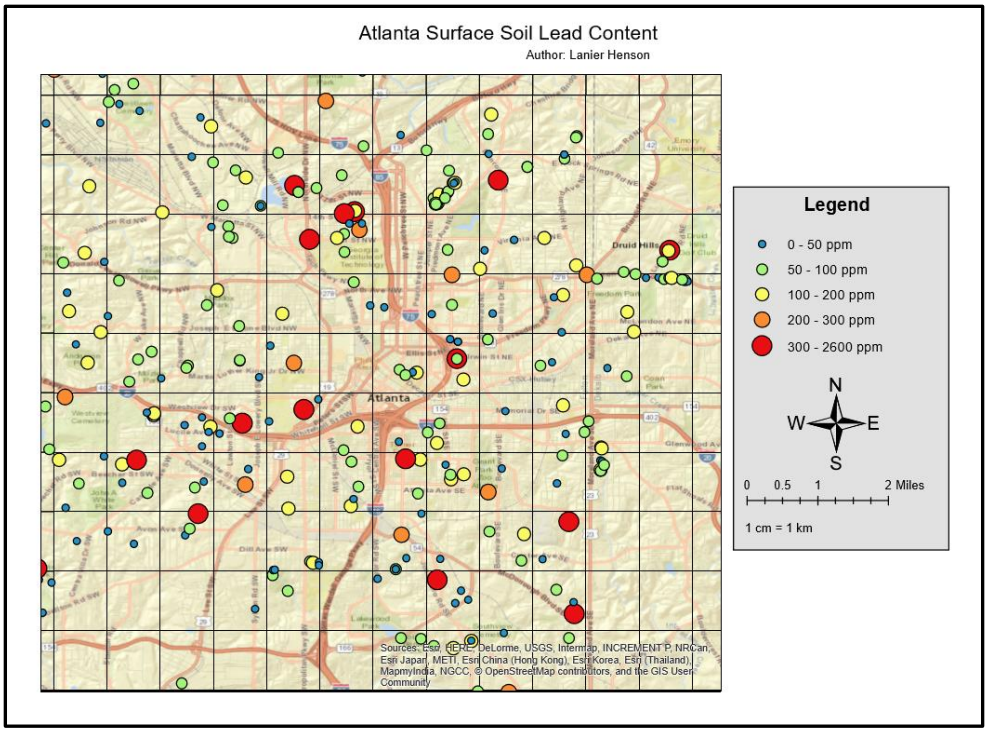

Figure 14: Soil Lead Concentrations of Bulk Soil Samples through XRF Analysis of Downtown Urban Core

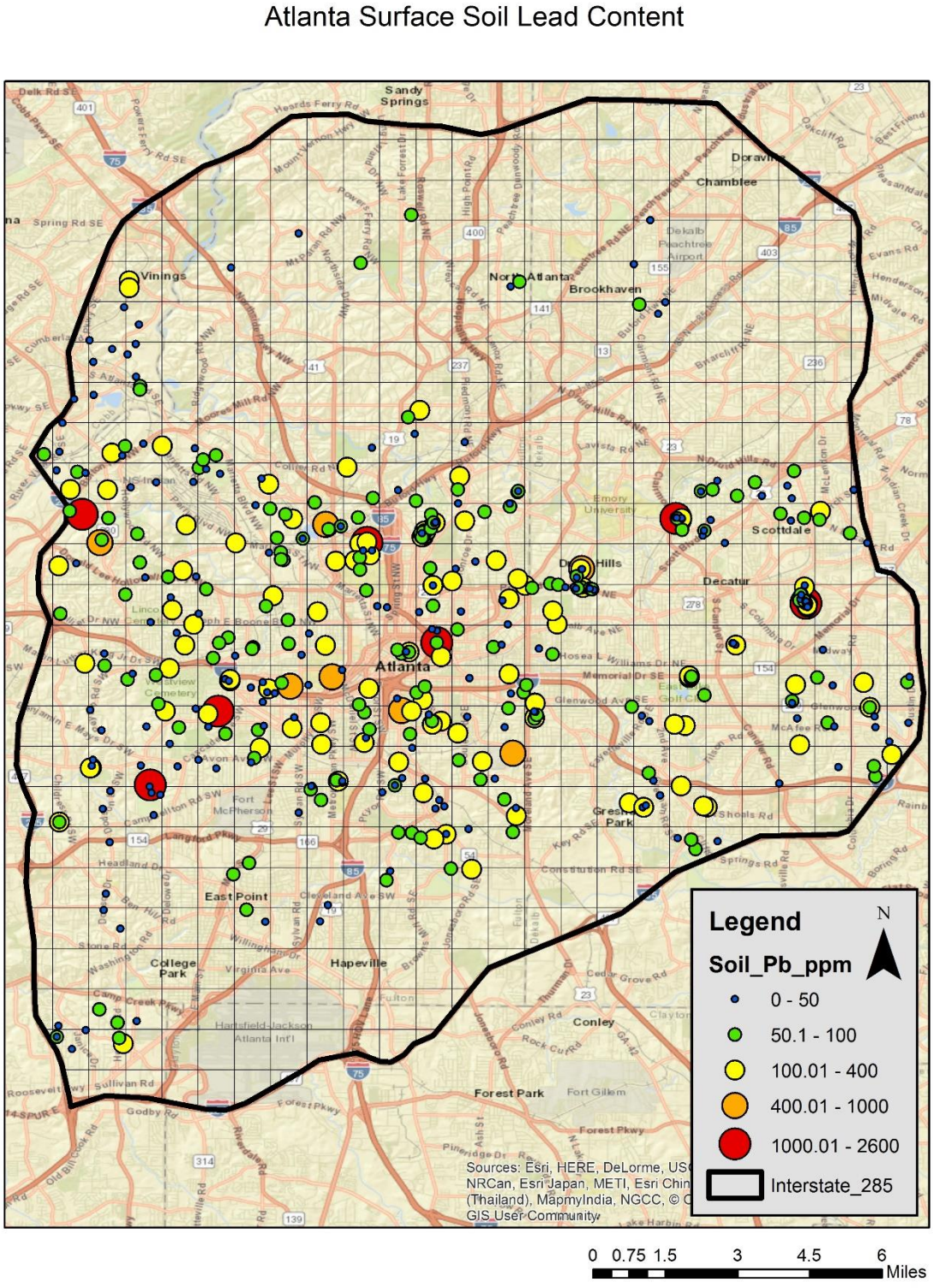

Figure 15: Soil Lead Concentrations of Bulk Soil Samples through XRF Analysis

4.1.2 Fine Grain Sample Analysis

All 750 soil samples were analyzed through a hand-held, Innov-X, α-4000 X-ray Fluorescence (XRF) spectrometer at Georgia State University. Before analysis, each sample was oven dried at 120 degrees Celsius for 12 hours to desiccate the soil. Removing all the soil moisture was necessary to separate the 100-micron fraction through sieving. Samples were analyzed twice then results were averaged. The fine grain fraction is more homogenous than the bulk samples requiring fewer tests per sample. The Environmental Protection Agency's (EPA) does not have a separate action level for lead within the fine grain fraction. Twenty-four samples were over the 400 ppm concentration used to regulate soil contamination. The max concentration was 3029 ppm and the minimum concentration was 10 ppm. Figure 18, illustrates the the highest concentrations were found dispersed throughout the region and the interpolated concentrations between the sample locations through inverse distance weighting. Figures 16, a histogram of the measured soil lead concentrations displays the higher median values than found in the bulk soil samples. The median concentration was 75 ppm and the mean were 145ppm as displayed in table 1. The large difference in values are due to the presence of a few extremely high outliers within the dataset.

	100-Micron Fraction	Bulk Soil Samples
Mean	144.77	114.06
Median	75.00	59.19
Std deviation	297.33	251.31
Min	7.00	4.99
Max	3029	2466.74

Table 1: Descriptive Statistics of XRF Analysis

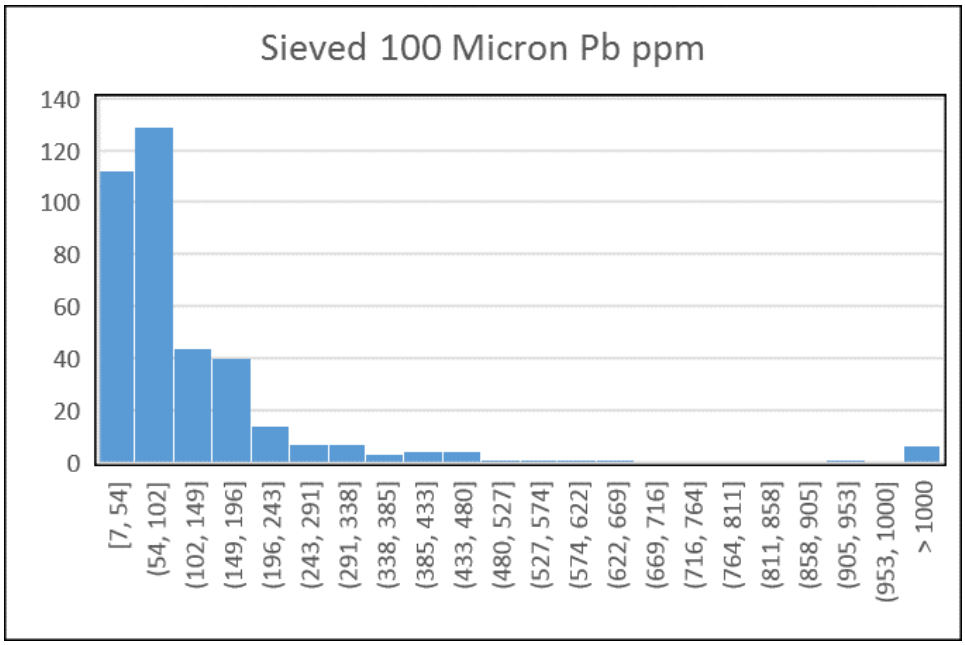

Figure 16: Histogram of Soil Lead Concentrations within the 100-Micron Fraction through Handheld XRF Analysis

4.1.3 Comparison of Bulk Soil sample and 100-Micron fraction Soil Lead

Three hundred and seventy-six samples were analyzed through a hand-held, Innov-X, α-4000 X-ray Fluorescence (XRF) spectrometer at Georgia State University for both the bulk soil lead concentration and the 100-micron fine grain fraction. Two hundred and sixty-six samples, or approximately seventy-one percent of the samples had an increase in overall concentration between the bulk and fine grain analysis. The median increase in soil lead concentration between the two analyses was 31 ppm with a mean increase in soil lead concentration of 97 ppm. As displayed in figure 17, the scatter plot of the two datasets plotted against on another the bulk soil lead concentration cannot very accurately predict the concentrations within the fine grain fraction, likely due to the heterogeneity of the sample.

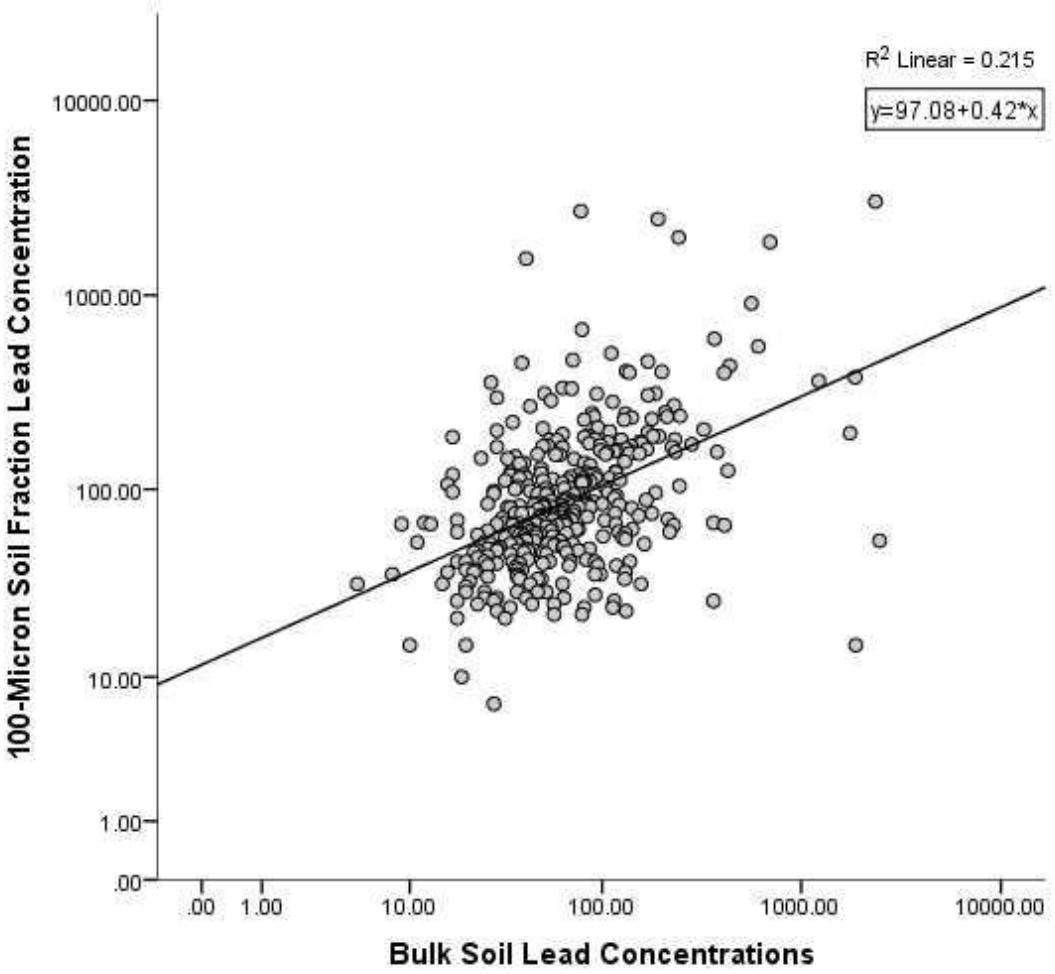

Figure 17: Scatter Plot Comparison of 100-Micron Fraction of Soil Lead to Bulk Sample Analysis Utilizing Handheld XRF

4.2 Spatial Distribution

4.2.1 Inverse Distance Weighting of 100-Micron size fraction Lead Concentrations

Figure 18, is the predictive map of fine grain soil lead concentrations within the Atlanta urban environment generated through inverse distance weighting. Because of the large difference in spatial autocorrelation of lead and the sampling distance, as evident of the large nuggets in figures 24 and 29. Figures 20 through 24 are the descriptive statistics of the measured sample locations used to generate the predictive map and the descriptive statistics of

the predicted values. The inverse distance map should only be used to aid in determining large regional trends for the environment and any individual location, not sampled in the data set should be sampled separately rather than extrapolating data from the map. The predictive map provides useful visual trends of qualitative relationships which would not be possible to find when viewing as a table. There are localized regions or enrichment as well as background levels. There is a strong visible trend of increased soil lead concentrations in the East-West direction. Additionally, the downtown Urban core has a large concentration of elevated soil lead values within this fine grain fraction. Inverse distance weighting was used instead of kriging, the more accurate analysis, because visually the kriging results did not seem realistic.

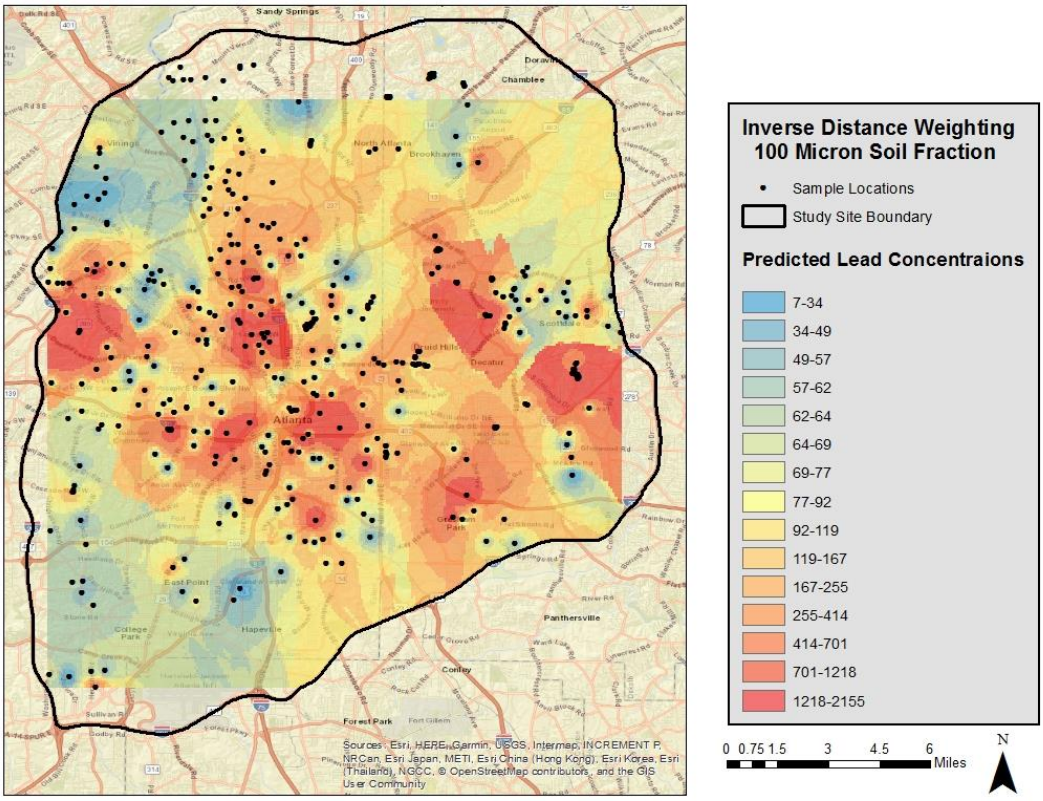

Figure 18: Inverse Distance Weighting Predictive Map of 100-Micron Soil Fraction

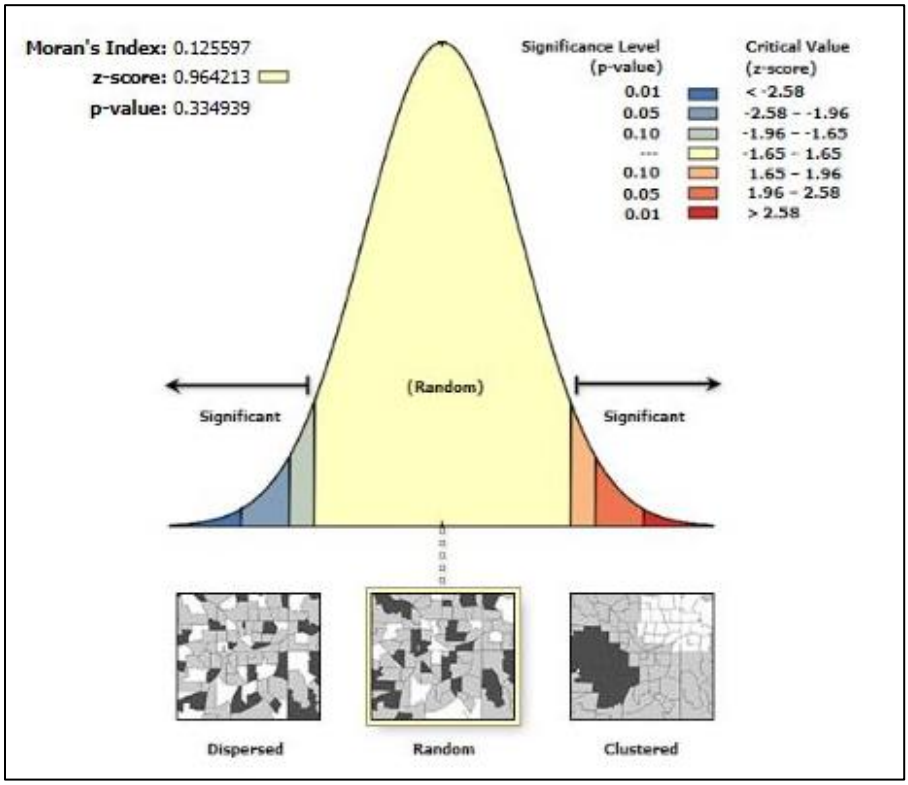

Figure 19: Spatial Auto Correlation Report of 100-Micron Soil Fraction

The Moran's I analysis for spatial autocorrelation was performed on the dataset used to generate the predictive map using Inverse distance weighting. The Moran's I tool within the ArcMap generates three values: Z-score, p-value, and Moran's Index. The Z-score was 0.964213, and when plotted on the bell curve indicates the degree randomness the samples process in their distribution of values. Interpolation results are not reliable because of the randomness found in the distribution. In this case, the z-score suggests the samples are not spatially autocorrelated in terms of soil lead concentrations within the 100-micron fraction at this sampling interval. The p-value was 0.334939, which further suggests in relation to the soil lead concentration points are randomly dispersed.

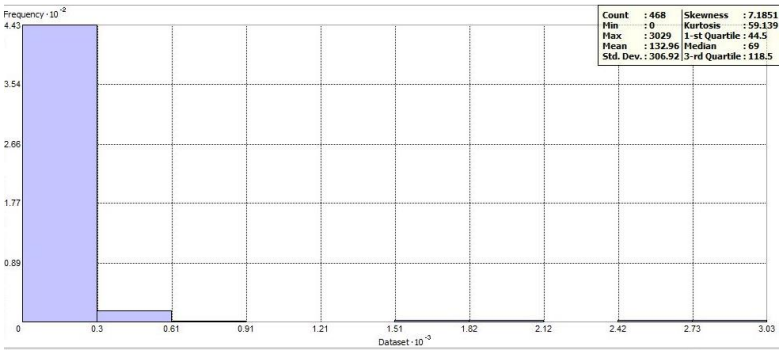

Figure 20: Histogram, Inverse Distance Weighting Observed Soil Lead Concentrations

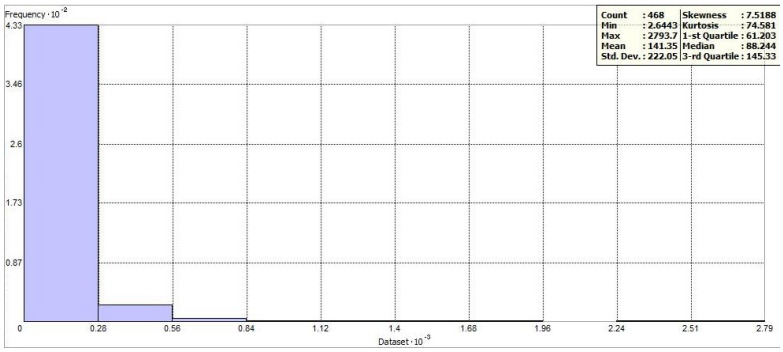

Figure 21: Histogram, Inverse Distance Weighting Predicted Soil Lead Concentrations

Figures 20 and 21 are histograms plotted from the measure and predicted values of the 100-micron soil fraction inverse distance weighting predictive map. Four hundred and sixty-eight samples were used to generate the inverse distance weight map and to generate the histograms. The measured values have a skewness value of 7.1851 and the predicted have a skewness of 7.5188, therefore both datasets are highly positively skewed. Due to nature high degree of skewness, neither the measured or predicted datasets are parametric.

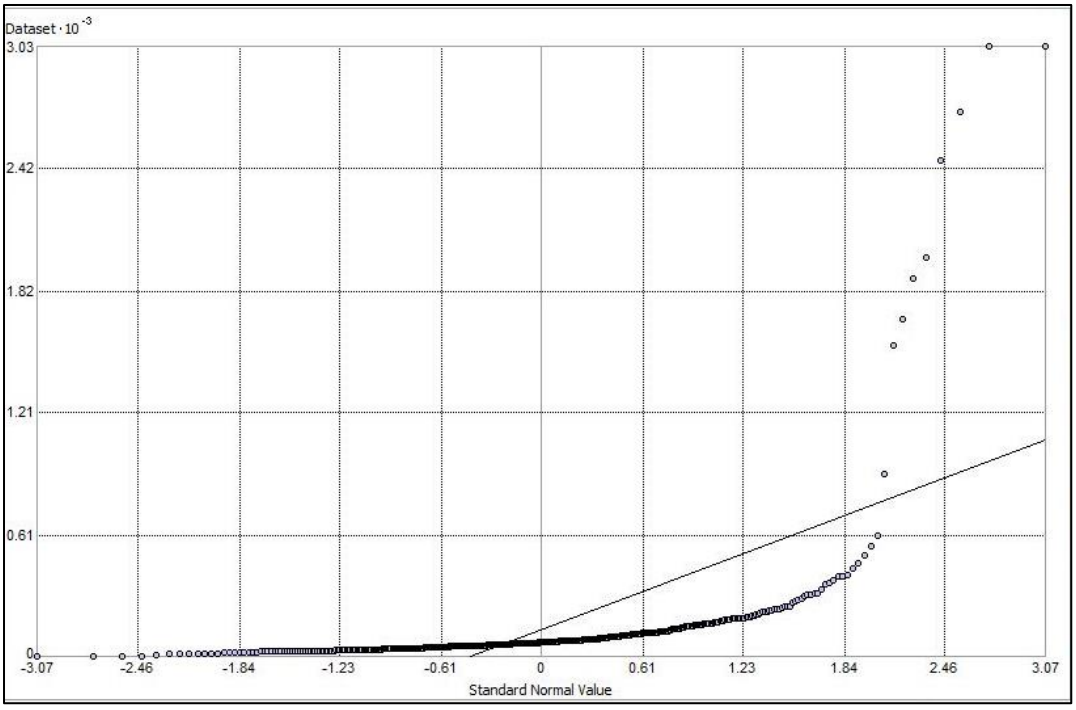

Figure 22: Normal QQ plot, Measured Lead Concentration

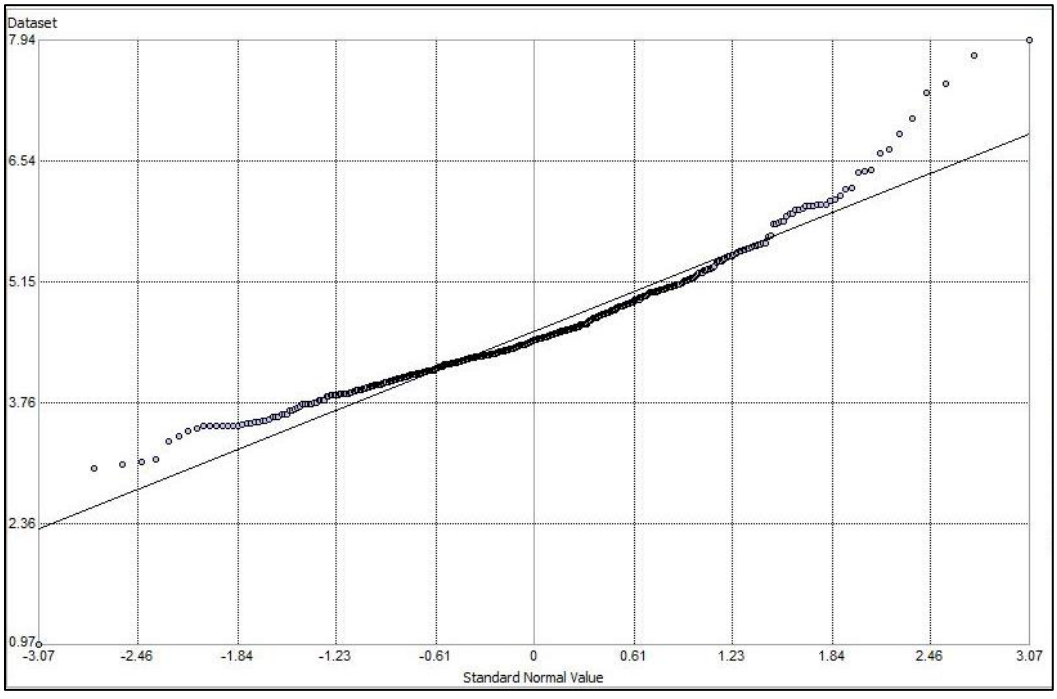

Figure 23: Normal QQ plot, Predicted Lead Concentration

Figure 22 and 23 are normal Q-Q plots for the measured and predicted values of the four hundred and sitxy-eight soil lead concentration values used to generate the inverse distance weighting predictive map. A normal Q-Q plot determines the skewnes or normality of the distribution within a dataset. Figure 242exhibts an extremely dramatic curve below the ploted refernece line, indicating the dataset is heavily skewed. Because the divergence from the reference line is least near the zero value we know the departure from a normal distribution ocurrs from our extreme values. This is in agreance with the histogram of the same data, figure 20. Figure 23 shows a more normalized distribution, but this is because the values are generated. We still have evidence of divernce from normal however along the extremes of the lead concentrations.

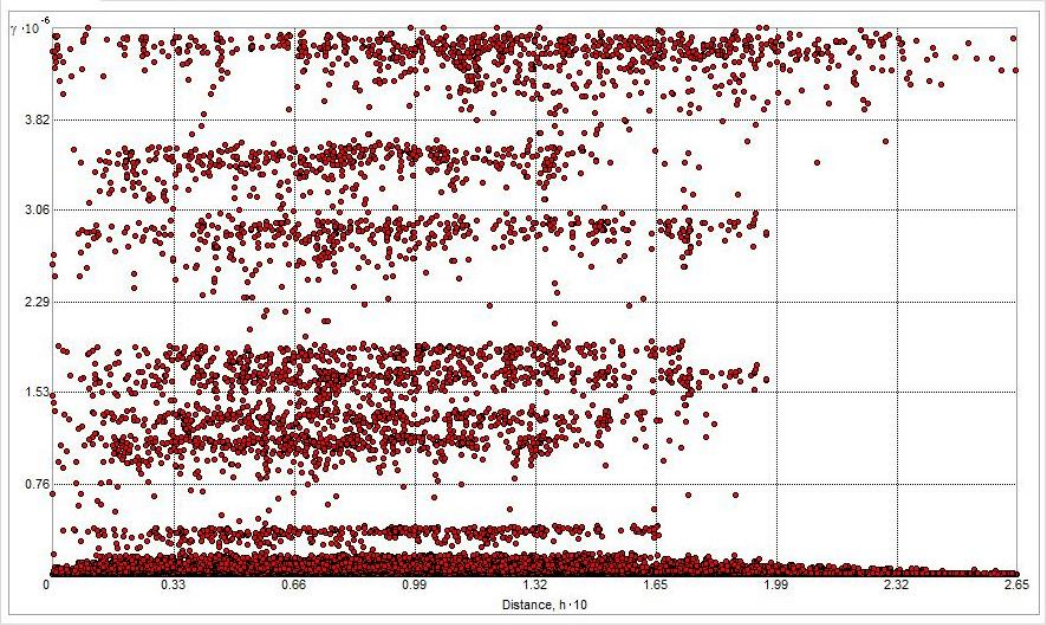

Figure 24: Semivariogram, Measured Soil Lead Concentrations

Figures 24 shows the semivariogram plots for the measured and predicted soil lead datasets used to generate the inverse distance weighting predictive map. Semivariograms are usefully in determining the spatial autocorrelation of a factor between two locations. The data have generated multiple nuggets, meaning there is another factor greatly influencing the spatial autocorrelation and the data would need to be grouped first by that factor before it is appropriate to use any interpolation results between points. In Figure 24, the measured samples have five distinct clusters of samples. A large majority of the values lay within the lowest cluster, which has an extremely low nugget, which would make it useful for interpolation, but without first determining the variable causing the clustering this is not possible.

4.2.2 Inverse Distance Weighting of Bulk Lead Concentrations

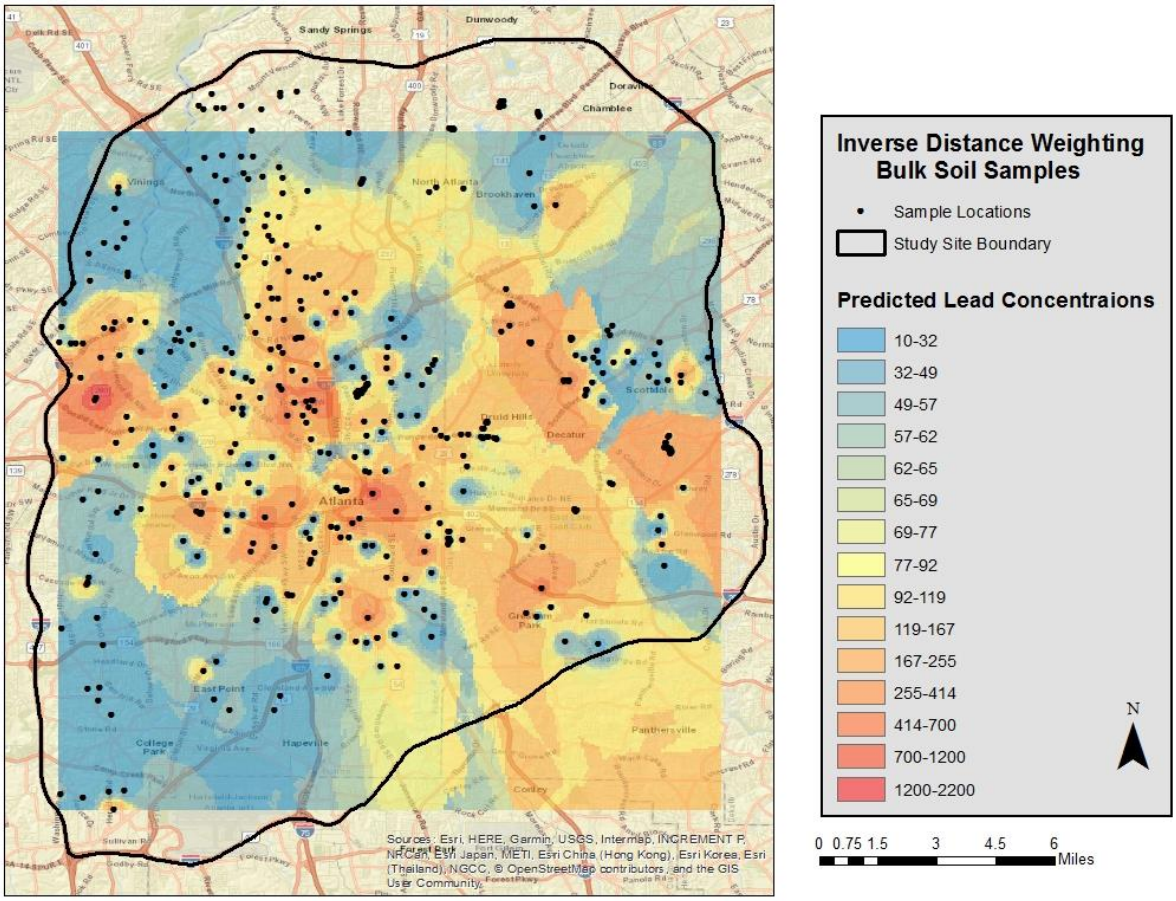

Figure 25: Predictive Soil Lead Concentrations within Bulk Soil through Inverse Distance Weighting

Figure 25, is the predictive map of Bulk soil lead concentrations within the Atlanta urban environment generated through inverse distance weighting. Figures 27 through 31 are the descriptive statistics of the measured sample locations used to generate the predictive map and the descriptive statistics of the predicted values. The inverse distance map should only be used to aid in determining large regional trends for the environment and any individual location, not sampled in the data set should be sampled separately rather than extrapolating data from the map. The predictive map provides useful visual trends of qualitative relationships which would

not be possible to find when viewing as a table. There are localized regions or enrichment as well as background levels. There is a strong visible trend of increased soil lead concentrations in the East-West direction. Additionally, the downtown Urban core has a large concentration of elevated soil lead values within this fine grain fraction. Inverse distance weighting was used instead of kriging, the more accurate analysis, because visually the kriging results did not seem realistic.

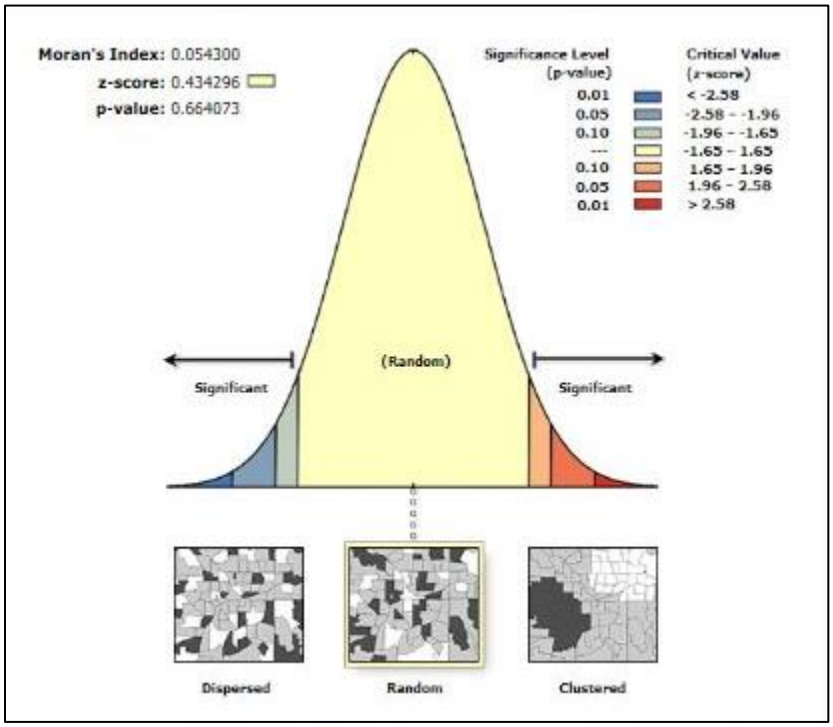

Figure 26: Spatial Auto Correlation Report of Bulk Soil Samples

The Moran's I analysis for spatial autocorrelation was performed on the dataset used to generate the predictive map using Inverse distance weighting. The Moran's I tool within the ArcMap generates three values: Z-score, p-value, and Moran's Index. The Z-score was 0.434296, and when plotted on the bell curve indicates the degree randomness the samples process in their distribution of values. Interpolation results are not reliable because of this random distribution. In this case, the z-score suggests the samples are not spatially

autocorrelated in terms of soil lead concentrations within the 100-micron fraction at this sampling interval. The p-value was 0.664073, which further suggests in relation to the soil lead concentration points are randomly dispersed.

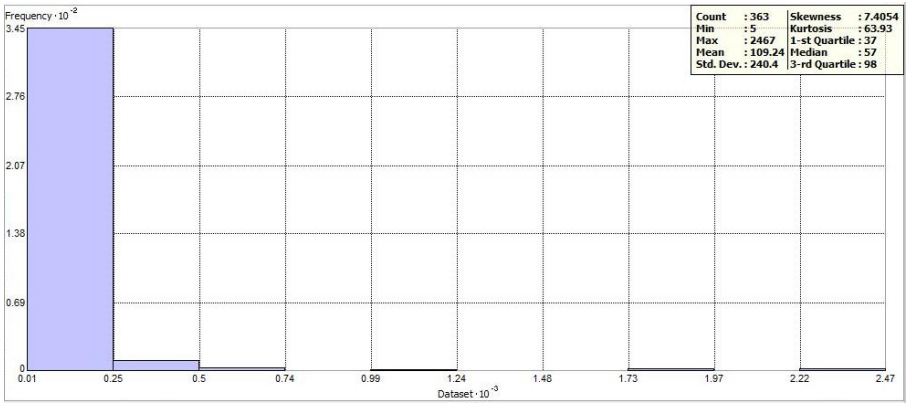

Figure 27: Histogram, Inverse Distance Weighting Measured Soil Lead Concentrations

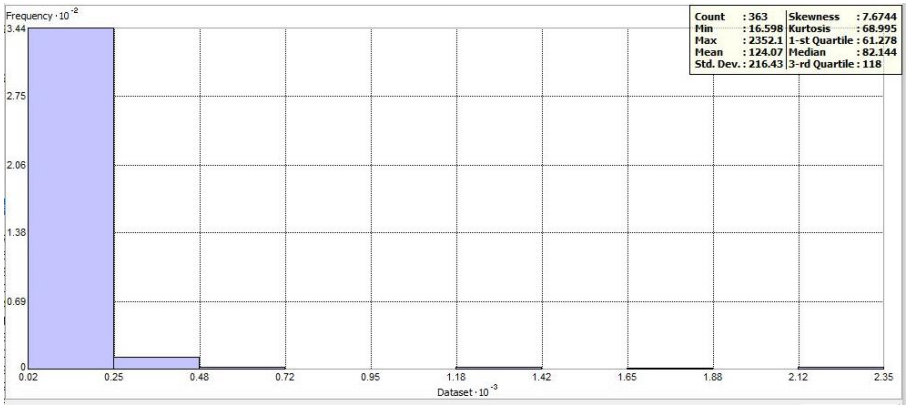

Figure 28: Histogram, Inverse Distance Weighting Predicted Soil Lead Concentrations

Figures 27 and 28 are histograms plotted from the measure and predicted values of the 100-micron soil fraction inverse distance weighting predictive map. Three hundred and sixty-three samples were used to generate the inverse distance weight map and to generate the histograms. The measured values have a skewness value of 7.4054 and the predicted have a skewness of

7.6744, therefore both datasets are highly positively skewed. Due to nature high degree of skewness, neither the measured or predicted datasets are parametric.

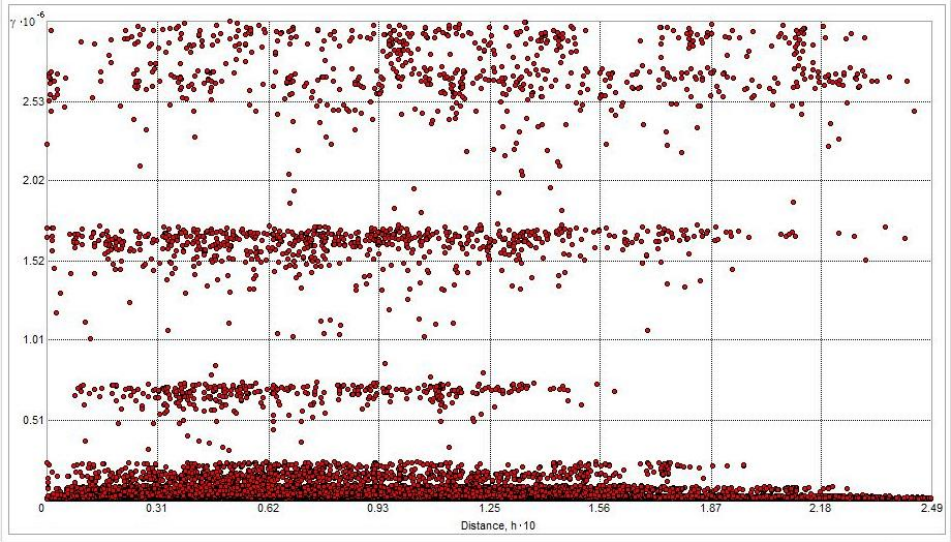

Figure 29: Semivariogram, Measured Soil Lead Concentration

Figures 29 is the semivariogram plots for the measured and predicted soil lead datasets used to generate the inverse distance weighting predictive map. Semivariograms are usefully in determining the spatial autocorrelation of a factor between two locations. The data has generated multiple nuggets, meaning there is another factor greatly influencing the spatial autocorrelation and the data would need to be grouped first by that factor before it is appropriate to use any interpolation results between points. Figure 29, the measured samples has four distinct clusters of samples. A large majority of the values lay within the lowest cluster, which has an extremely low nugget, which would make it useful for interpolation, but without first determining the variable causing the clustering this is not possible.

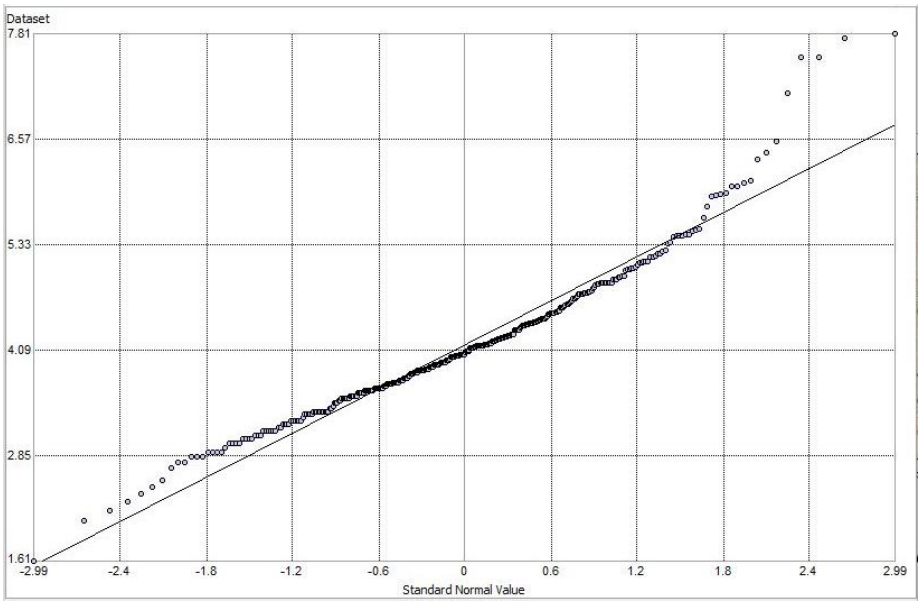

Figure 30: Normal QQ plot, Measured Lead Concentration

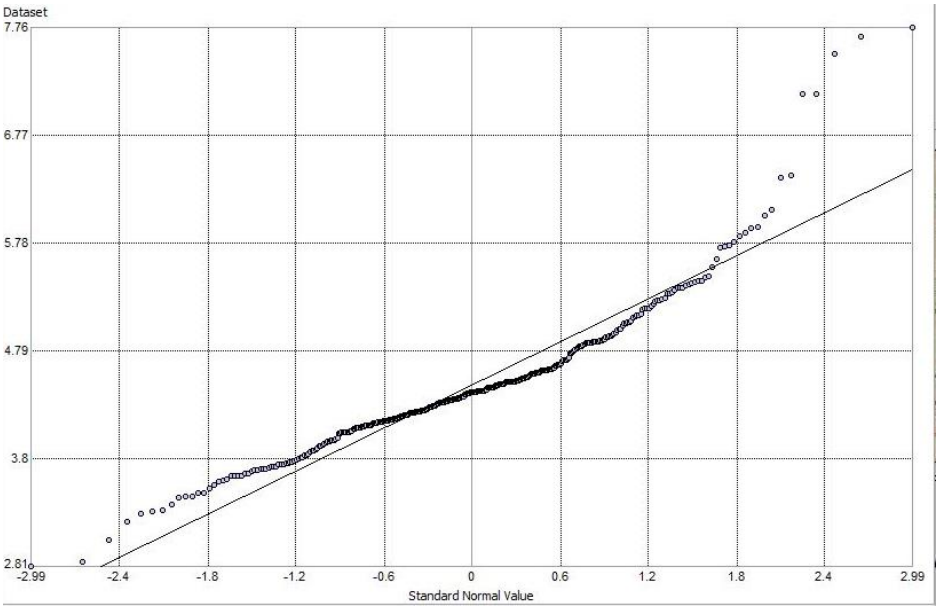

Figure 31: Normal QQ plot, Predicted Lead Concentration

Figure 30 and 31 are normal Q-Q plots for the measured and predicted values of the Three hundred and sixty-three sampled soil lead concentration values used to generate the inverse distance weighting predictive map. A normal Q-Q plot determines the skewness or normality of the distribution within a dataset. Figure 30 exhibits the greatest divergence from the plotted referenece line along the highest values, which is causing the skewness in the dataset. This may explain the high skewness value determined from the histogram of the same data, figure 30. Figure 31 shows greater divergence from a normalized distribution than the measured results of figure 30. The divergence from normal occurs across most of the range with only values less than the mean following a normal trend.

4.2.3 Soil Lead Concentrations

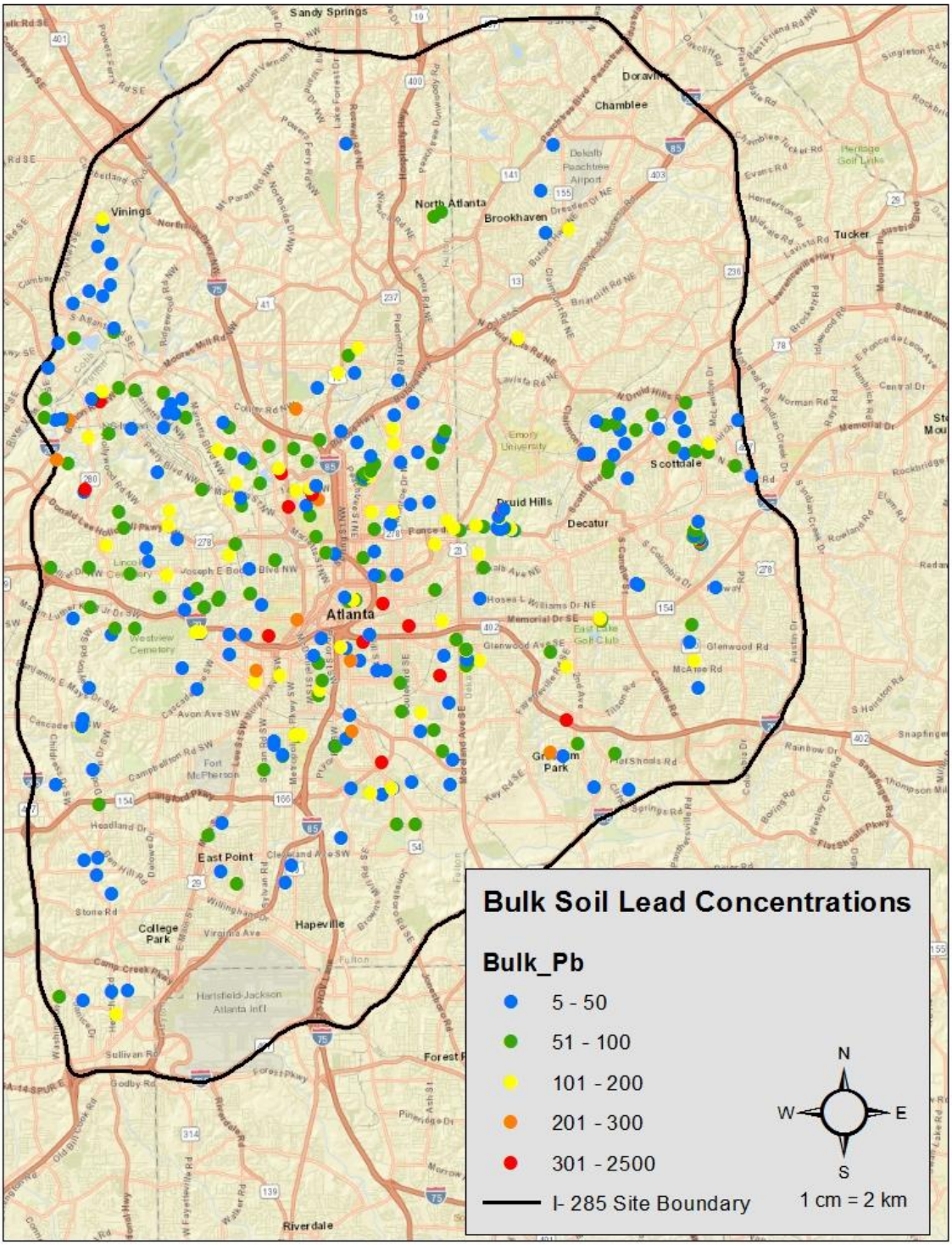

Figure 32: Bulk Soil Lead Concentration at Sample Locations

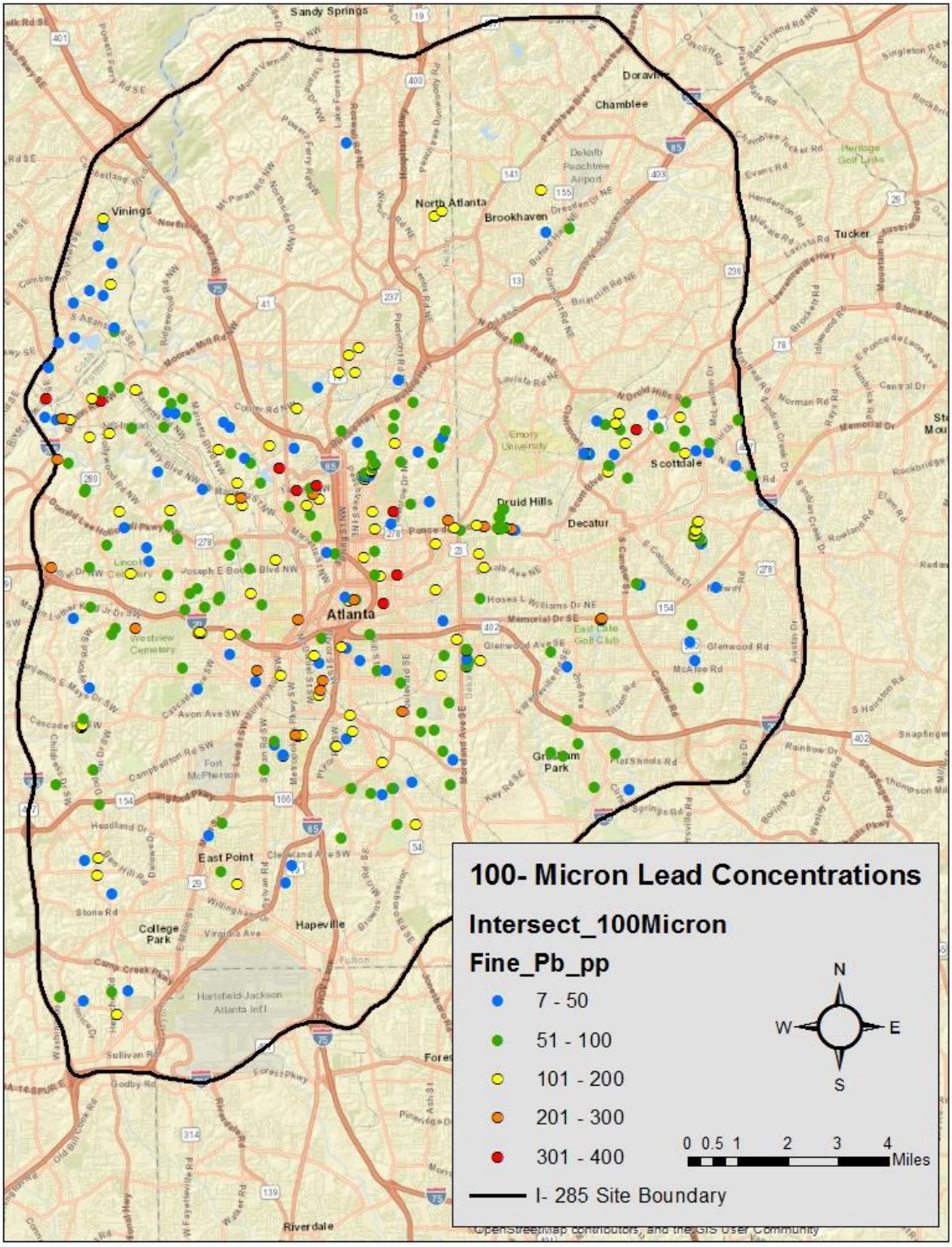

Figure 33: 100-Micron Soil Fraction Lead Concentrations at Sample Locations

4.3 Statistical Analysis

4.3.1 Soil Lead Concentrations and Bedrock Geology

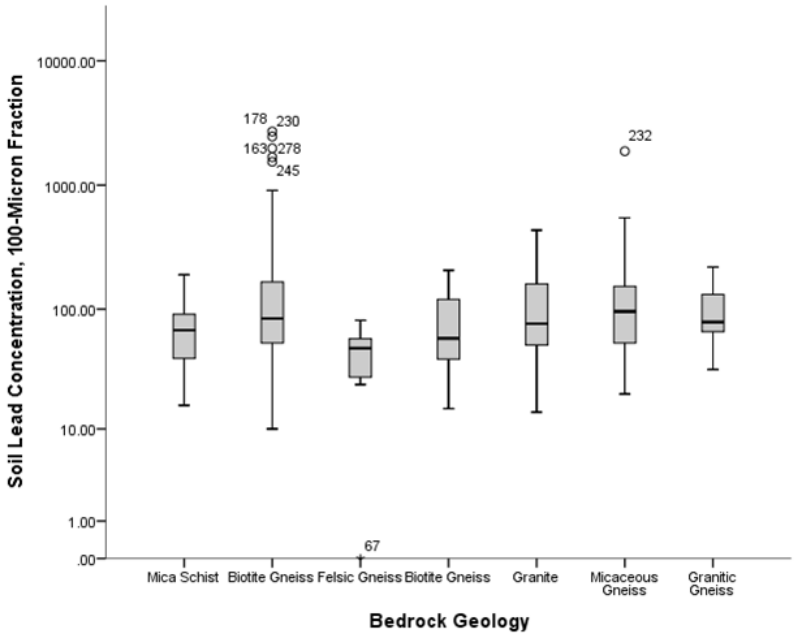

Figure 34: 100-Micron Soil Lead Concentrations as function of bedrock Geology

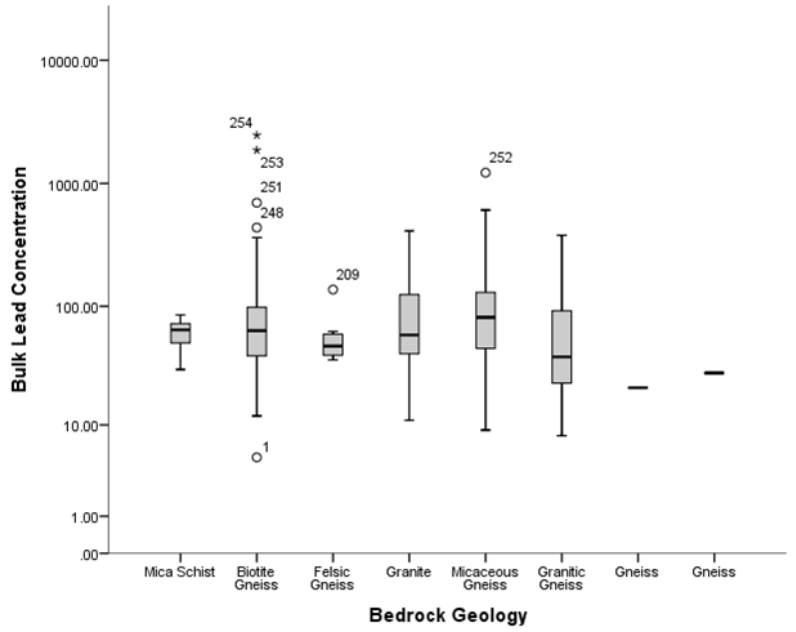

Figure 35: Bulk Soil Lead Concentrations as function of bedrock Geology

Figures 34 and 35 are comparative box plot graphs of soil lead concentration per bedrock rock type using a logarithmic scale for both the 100-micron soil fraction and the bulk soil lead concentrations. The whiskers of each box plot represent the minimum and maximum values for each bedrock type. Extreme soil lead concentrations are plotted as individual points above and below each box plot. The interior of the box plots represents the median, 75% quartile above the median, and 25% quartile below the median. For both the bulk soil samples and the fine grain samples, biotite gneiss contains the soils with the greatest enrichment of lead. The mean and ranges of soil lead concentrations for both the bulk and fine grain samples do not vary greatly across the different bedrock rock types. The soil lead concentration has the least range of both data sets of the felsic gneiss samples.

4.3.2 Soil Lead Concentrations and Soil Type

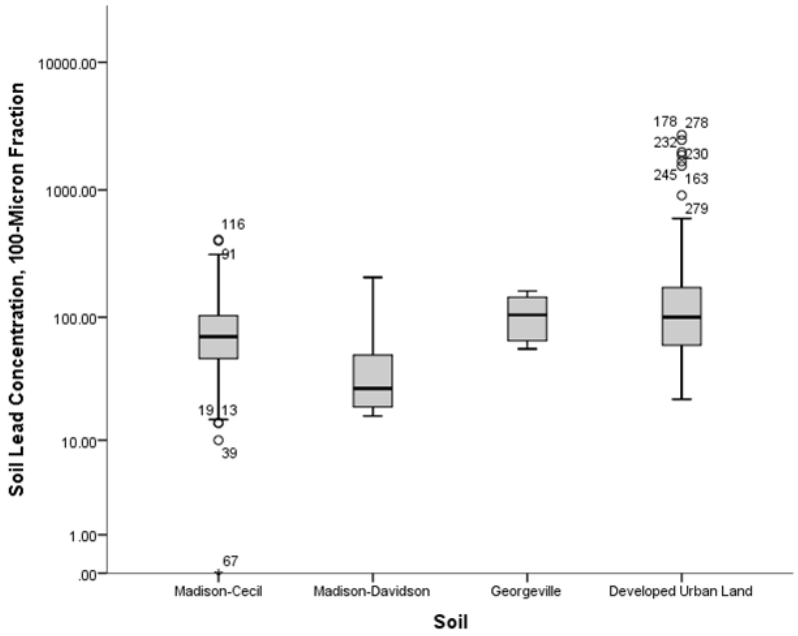

Figure 36: 100-Micron Soil Lead Concentrations as function of State USDA Soil Type

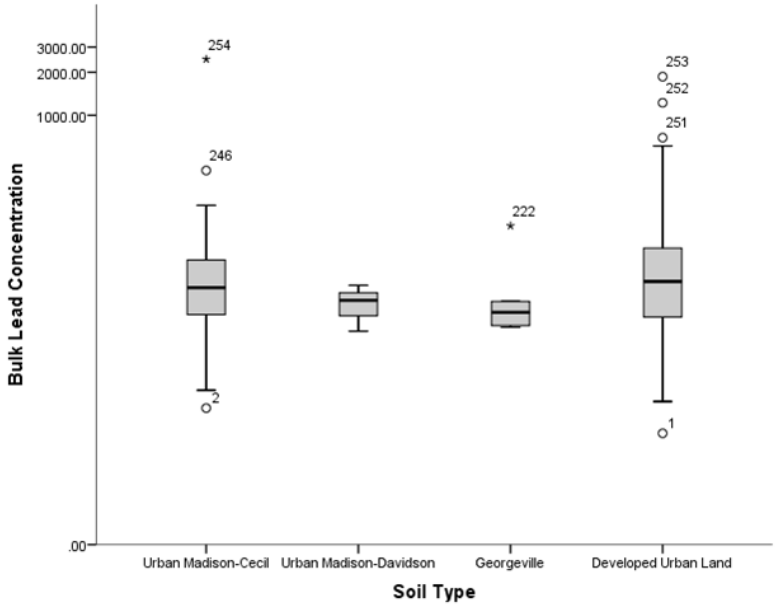

Figure 37: Bulk Soil Lead Concentrations as function of State USDA soil Type

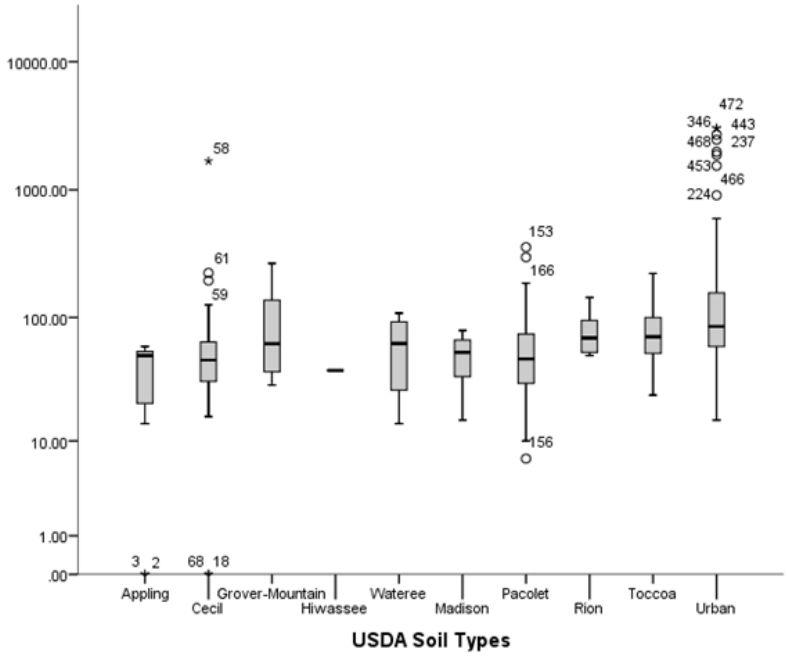

Figure 38: Bulk Soil Lead Concentration as a function of County USDA Soil Survey

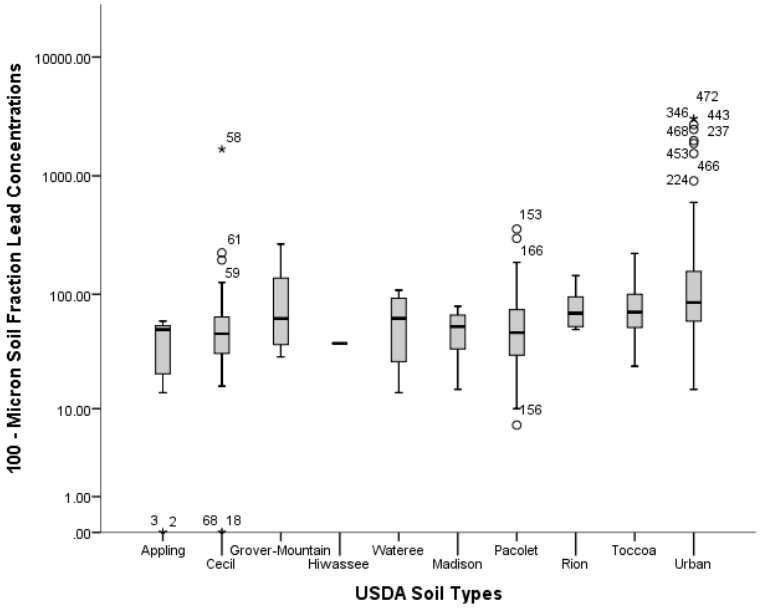

Figure 39: 100-Micron Soil Fraction Lead Concentration as Function of County USDA Soil Survey

Figures 36 through 38 are comparative box plot graphs of soil lead concentration per USDA soil type type using a logarithmic scale for both the 100-micron soil fraction and the bulk soil lead concentrations. The whiskers of each box plot represent the minimum and maximum values for each bedrock type. Extreme soil lead concentrations are plotted as individual points above and below each box plot. The interior of the box plots represents the median, 75% quartile above the median, and 25% quartile below the median. Figure 36 and 37 represent the soil lead concentrations plotted by soil types classified by the USDA soil survey for the entire state. Soil Types for Figure 38 and 39 were classified using the cooperative soil survey compiled by the USDA for each county. In all four diagrams, the urban soils have the highest concentrations as well as the largest ranges. The median lead concentrations are lower than the concentrations of the fine grain soil samples.

4.3.3 Soil Lead Concentrations and Land Use

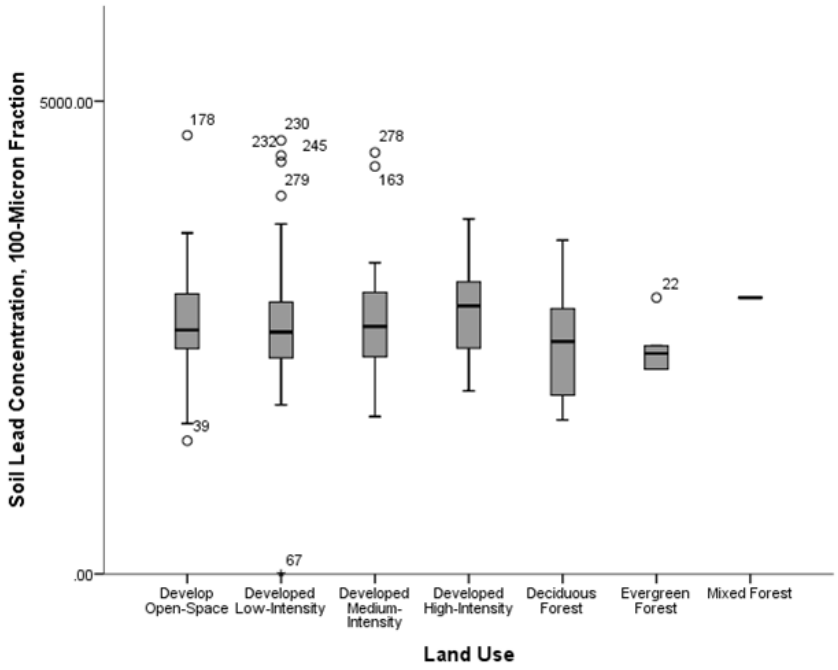

Figure 40: 100-Micron Soil Lead Concentrations as function of Land Use

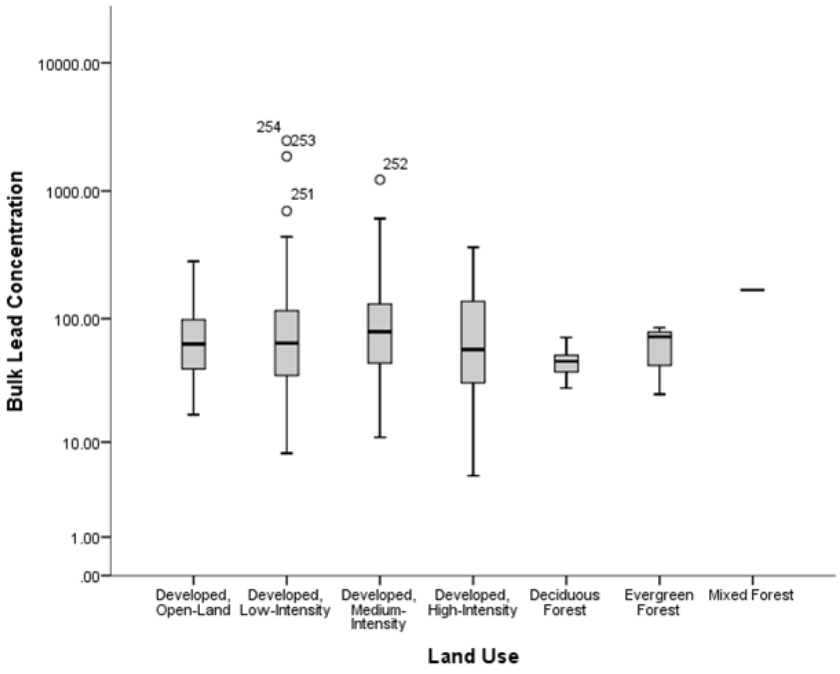

Figure 41: Bulk Soil Lead Concentrations as function of Land Use

Figures 40 and 41 are comparative box plot graphs of soil lead concentration plotted by land use and land cover using a logarithmic scale for both the 100-micron soil fraction and the bulk soil lead concentrations. The whiskers of each box plot represent the minimum and maximum values for each bedrock type. Extreme soil lead concentrations are plotted as individual points above and below each box plot. The interior of the box plots represents the median, 75% quartile above the median, and 25% quartile below the median. The median soil lead concentrations for the fine grain 100-micron fraction are significantly larger than those found within the bulk soil samples. Ranges for the bulk concentrations were consistent between land use compared to those of the fine grain samples. Within both data sets the greatest number of outliers to lie within the urban low-intensity land use category.

4.3.4 Soil Lead Concentrations and Atlanta Neighborhood Planning Units

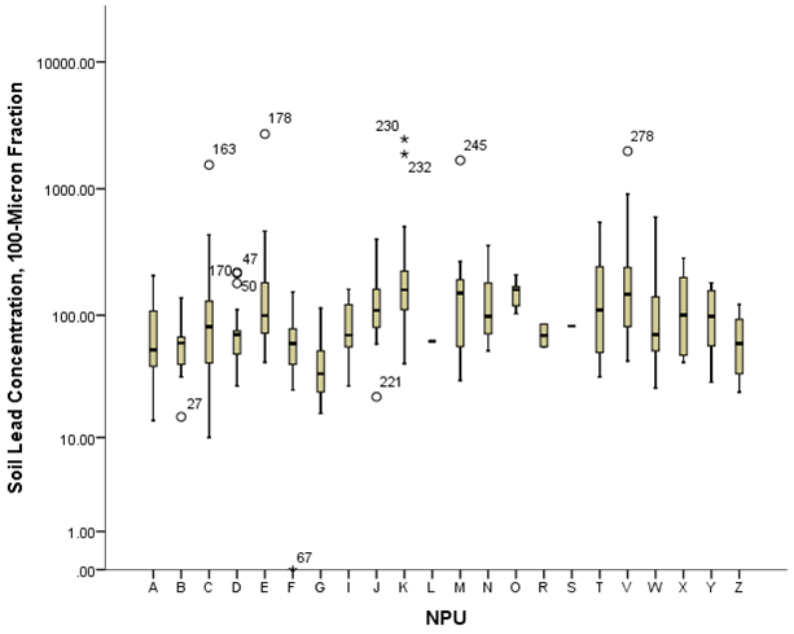

Figure 42: 100-Micron Soil Lead Concentrations as function of City of Atlanta Neighborhood Planning Units

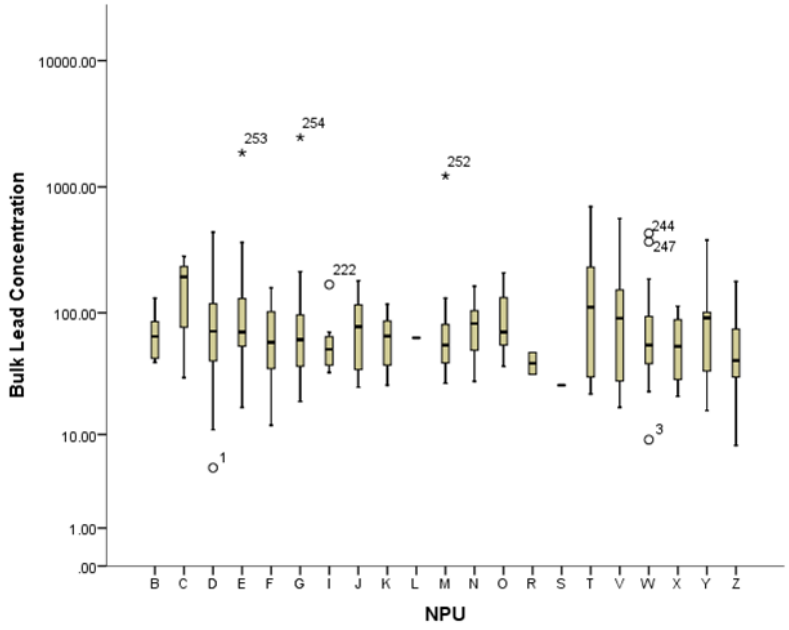

Figure 43: Bulk Soil Lead Concentrations as function of City of Atlanta Neighborhood Planning Units

Figures 42 and 43 are comparative box plot graphs of soil lead concentration plotted by the 2015 city of Atlanta neighborhood planning units (NPUs) using a logarithmic scale for both the 100-micron soil fraction and the bulk soil lead concentrations. The whiskers of each box plot represent the minimum and maximum values for each bedrock type. Extreme soil lead concentrations are plotted as individual points above and below each box plot. The interior of the box plots represents the median, 75% quartile above the median, and 25% quartile below the median. Between neighborhood planning units neither the ranges nor median soil lead concentrations for either dataset. There is greater variation between NPUs within the 100-micron soil fraction than the bulk samples, however. The 100-micron soil fraction also contains a greater number of outliers than present in the bulk samples.

4.3.5 Soil Lead Concentrations and Population Density

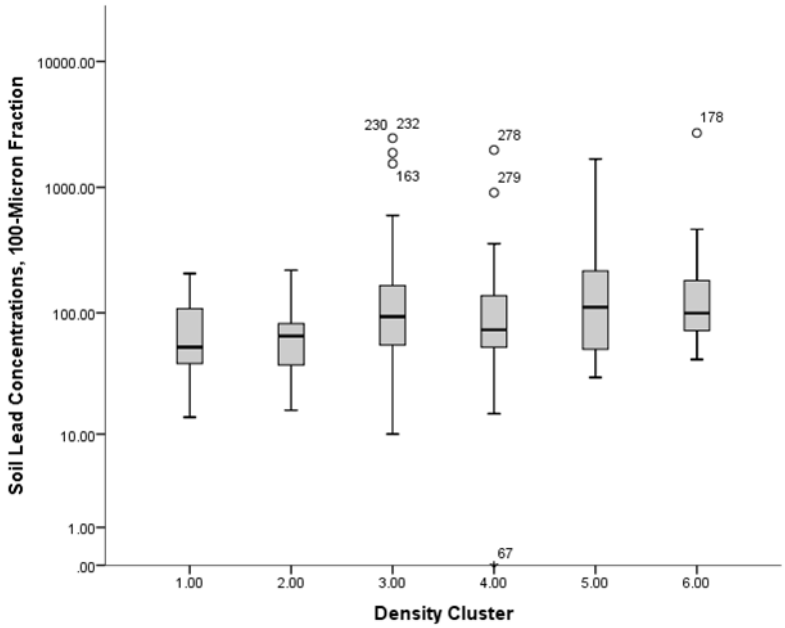

Figure 44: 100-Micron Soil Lead Concentrations as function Population Density

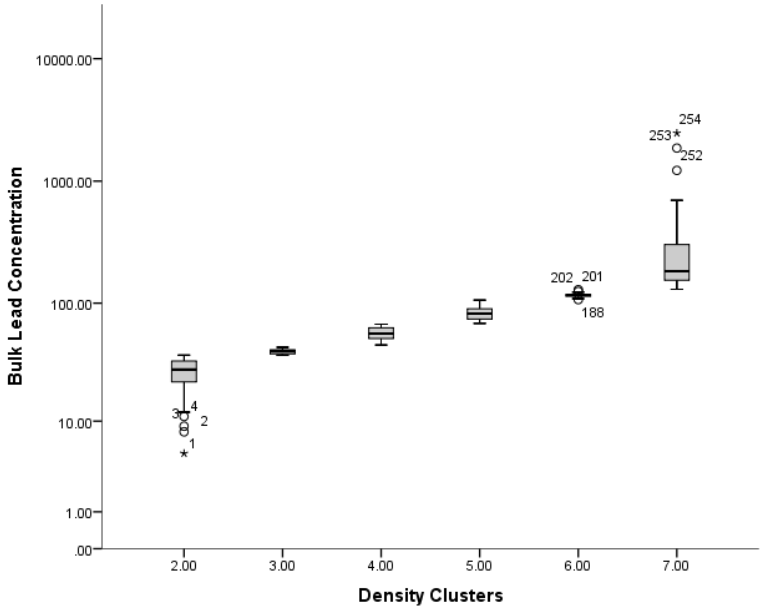

Figure 45: Bulk Soil Lead Concentrations as function Population Density

Figures 44 and 45 are comparative box plot graphs of soil lead concentration plotted by populations density cluster using a logarithmic scale for both the 100-micron soil fraction and the bulk soil lead concentrations. The population density cluster was generated by grouping the population densities of the various NPUs for the city of Atlanta in seven increasing groups. The whiskers of each box plot represent the minimum and maximum values for each bedrock type. Extreme soil lead concentrations are plotted as individual points above and below each box plot. The interior of the box plots represents the median, 75% quartile above the median, and 25% quartile below the median. The entire range of values between bulk and fine grain samples are similar. Within the bulk soil samples, the ranges of each cluster are significantly smaller than those of the 100-micron soil fraction samples. Within the 100-micron soil fraction samples, the outliers are distributed between across the various clusters. Within the bulk soil samples outliers exist within the least and most populated clusters. Median soil lead concentrations within the bulk soil samples increase as a function of population density and there is very little overlap of ranges between clusters.

4.3.6 Matrix of Correlation

r	S	K	Ca	Ti	Cr	Mn	Fe	Co	Cu	Zn	As	Rb	Sr	Zr	Cd	Ba	Pb
S	1	-0.099	-0.051	0.403	0.048	0.185	0.663	-0.027	0.127	0.095	-0.023	-0.137	-0.202	-0.019	-0.007	0.441	0.131
K	-0.099	1	0.06	-0.165	-0.111	0.045	-0.1	-0.002	-0.005	0.003	-0.101	0.704	0.329	-0.132	-0.015	0.056	0.014
Ca	-0.051	0.06	1	-0.191	0.015	0.171	-0.066	-0.005	0.072	0.242	0.017	-0.06	0.473	-0.162	-0.039	-0.061	0.132
Ti	0.403	-0.165	-0.191	1	0.172	0.343	0.639	0.1	0.144	0.013	0.076	-0.211	-0.247	0.52	0.036	0.465	0.005
Cr	0.048	-0.111	0.015	0.172	1	0.103	0.162	0.097	0.217	0.031	0.014	-0.115	0.051	0.091	0.001	0.301	0.005
Mn	0.185	0.045	0.171	0.343	0.103	1	0.34	0.341	0.257	0.088	0.052	-0.021	-0.064	0.059	-0.029	0.239	0.013
Fe	0.663	-0.1	-0.066	0.639	0.162	0.34	1	0.059	0.234	0.029	-0.013	-0.206	-0.251	-0.005	0.016	0.655	-0.019
Co	-0.027	-0.002	-0.005	0.1	0.097	0.341	0.059	1	0.18	-0.008	-0.023	-0.124	-0.02	0.025	-0.025	-0.056	0.001
Cu	0.127	-0.005	0.072	0.144	0.217	0.257	0.234	0.18	1	0.112	-0.012	-0.087	-0.001	-0.01	-0.01	0.249	0.161
Zn	0.095	0.003	0.242	0.013	0.031	0.088	0.029	-0.008	0.112	1	-0.019	-0.027	0.084	-0.011	-0.026	0.058	0.582
As	-0.023	-0.101	0.017	0.076	0.014	0.052	-0.013	-0.023	-0.012	-0.019	1	-0.057	-0.008	0.106	0.001	0.024	-0.033
Rb	-0.137	0.704	-0.06	-0.211	-0.115	-0.021	-0.206	-0.124	-0.087	-0.027	-0.057	1	0.141	-0.166	0.033	-0.056	0.013
Sr	-0.202	0.329	0.473	-0.247	0.051	-0.064	-0.251	-0.02	-0.001	0.084	-0.008	0.141	1	-0.109	-0.032	0.059	0.067
Zr	-0.019	-0.132	-0.162	0.52	0.091	0.059	-0.005	0.025	-0.01	-0.011	0.106	-0.166	-0.109	1	0.059	0.152	0.037
Cd	-0.007	-0.015	-0.039	0.036	0.001	-0.029	0.016	-0.025	-0.01	-0.026	0.001	0.033	-0.032	0.059	1	0.033	-0.022
Ba	0.441	0.056	-0.061	0.465	0.301	0.239	0.655	-0.056	0.249	0.058	0.024	-0.056	0.059	0.152	0.033	1	0.058
Pb	0.131	0.014	0.132	0.005	0.005	0.013	-0.019	0.001	0.161	0.582	-0.033	0.013	0.067	0.037	-0.022	0.058	1

Table 2: Matrix of Correlation of 100-Micron Soil Fraction XRF Results

Table 2, displays the correlation coefficients, r, calculated from a matrix of intercorrelation between elemental concentrations determined through handheld Xray fluorescence (XRF) for the 100-micron soil fractions. R values range between -1 and 1 depending on the strength and relationship between each of the pairs of elements. There were multiple strong positive correlations between elements and one moderate negative correlation. Lead, Pb, concentrations are not strongly associated with any of the other analyzed elements except Zinc, Zn. The r value between zinc and lead was .582. The strongest correlations are between Rubidium and Potassium, Iron and Sulphur, and Iron and Titanium. The correlation coefficients are 0.704, 0.663, and0.639 respectively. Strontium is also having a moderate correlation to Potassium, with a correlation coefficient of 0.329.

r	S	K	Ca	Ti	Mn	Fe	Cu	Zn	Rb	Sr	Zr	Ba	Pb
S	1	-0.082	-0.177	0.443	0.368	0.709	0.125	-0.149	-0.265	-0.282	0.008	0.45	-0.186
K	-0.082	1	-0.223	-0.061	-0.187	-0.257	-0.003	-0.002	0.603	0.19	-0.001	-0.059	-0.007
Ca	-0.177	-0.223	1	-0.193	0.104	-0.082	-0.012	0.344	-0.201	0.652	-0.177	-0.106	0.188
Ti	0.443	-0.061	-0.193	1	0.401	0.69	0.152	-0.052	-0.342	-0.073	0.543	0.248	-0.154
Mn	0.368	-0.187	0.104	0.401	1	0.564	0.064	-0.043	-0.198	0.027	0.067	0.172	-0.072
Fe	0.709	-0.257	-0.082	0.69	0.564	1	0.29	0.016	-0.544	-0.14	0.156	0.646	-0.192
Cu	0.125	-0.003	-0.012	0.152	0.064	0.29	1	0.122	-0.097	0.027	0.129	0.387	-0.138
Zn	-0.149	-0.002	0.344	-0.052	-0.043	0.016	0.122	1	-0.088	0.403	0.119	0.109	0.73
Rb	-0.265	0.603	-0.201	-0.342	-0.198	-0.544	-0.097	-0.088	1	-0.089	-0.188	-0.436	0.114
Sr	-0.282	0.19	0.652	-0.073	0.027	-0.14	0.027	0.403	-0.089	1	0.133	-0.022	0.238
Zr	0.008	-0.001	-0.177	0.543	0.067	0.156	0.129	0.119	-0.188	0.133	1	0.184	0.087
Ba	0.45	-0.059	-0.106	0.248	0.172	0.646	0.387	0.109	-0.436	-0.022	0.184	1	-0.098
Pb	-0.186	-0.007	0.188	-0.154	-0.072	-0.192	-0.138	0.73	0.114	0.238	0.087	-0.098	1

Figure 46: Density Cluster 1, Matrix of Correlation

r	S	K	Ca	Ti	Mn	Fe	Cu	Zn	Rb	Sr	Zr	Ba	Pb
S	1	-0.049	0.045	0.669	0.21	0.728	0.403	0.406	-0.234	-0.118	0.16	0.39	0.157
K	-0.049	1	-0.021	-0.06	-0.428	-0.146	0.014	0.184	0.894	0.366	0.163	-0.062	0.319
Ca	0.045	-0.021	1	-0.315	0.046	-0.166	-0.005	0.247	-0.131	0.617	-0.299	-0.218	0.219
Ti	0.669	-0.06	-0.315	1	0.189	0.747	0.268	0.297	-0.252	-0.383	0.611	0.367	0.039
Mn	0.21	-0.428	0.046	0.189	1	0.326	0.228	0.161	-0.476	-0.125	0.024	0.283	0.046
Fe	0.728	-0.146	-0.166	0.747	0.326	1	0.391	0.314	-0.34	-0.286	0.255	0.647	0.042
Cu	0.403	0.014	-0.005	0.268	0.228	0.391	1	0.566	-0.046	0.132	0.079	0.607	0.405
Zn	0.406	0.184	0.247	0.297	0.161	0.314	0.566	1	0.123	0.331	0.021	0.141	0.758
Rb	-0.234	0.894	-0.131	-0.252	-0.476	-0.34	-0.046	0.123	1	0.399	-0.07	-0.136	0.314
Sr	-0.118	0.366	0.617	-0.383	-0.125	-0.286	0.132	0.331	0.399	1	-0.24	-0.07	0.345
Zr	0.16	0.163	-0.299	0.611	0.024	0.255	0.079	0.021	-0.07	-0.24	1	0.231	-0.108
Ba	0.39	-0.062	-0.218	0.367	0.283	0.647	0.607	0.141	-0.136	-0.07	0.231	1	0.029
Pb	0.157	0.319	0.219	0.039	0.046	0.042	0.405	0.758	0.314	0.345	-0.108	0.029	1

Figure 47: Density Cluster 2, Matrix of Correlation

r	S	K	Ca	Ti	Mn	Fe	Cu	Zn	Rb	Sr	Zr	Ba	Pb
S	1	-0.152	-0.057	0.437	0.25	0.72	0.291	0.281	-0.123	-0.074	-0.053	0.591	0.261
K	-0.152	1	-0.077	-0.213	0.166	-0.111	-0.101	-0.009	0.791	0.307	-0.024	-0.125	0.011
Ca	-0.057	-0.077	1	-0.213	0.134	0.084	0.266	0.257	-0.182	0.338	-0.27	-0.009	0.193
Ti	0.437	-0.213	-0.213	1	0.2	0.605	0.163	0.201	-0.201	-0.171	0.419	0.522	0.169
Mn	0.25	0.166	0.134	0.2	1	0.367	0.314	0.274	0.138	0.079	-0.043	0.361	0.176
Fe	0.72	-0.111	0.084	0.605	0.367	1	0.386	0.269	-0.121	-0.162	-0.161	0.736	0.135
Cu	0.291	-0.101	0.266	0.163	0.314	0.386	1	0.411	-0.093	0.027	-0.07	0.401	0.328
Zn	0.281	-0.009	0.257	0.201	0.274	0.269	0.411	1	-0.113	0.173	-0.085	0.273	0.95
Rb	-0.123	0.791	-0.182	-0.201	0.138	-0.121	-0.093	-0.113	1	0.2	-0.019	-0.058	-0.097
Sr	-0.074	0.307	0.338	-0.171	0.079	-0.162	0.027	0.173	0.2	1	-0.105	0.011	0.187
Zr	-0.053	-0.024	-0.27	0.419	-0.043	-0.161	-0.07	-0.085	-0.019	-0.105	1	0.128	-0.02
Ba	0.591	-0.125	-0.009	0.522	0.361	0.736	0.401	0.273	-0.058	0.011	0.128	1	0.163
Pb	0.261	0.011	0.193	0.169	0.176	0.135	0.328	0.95	-0.097	0.187	-0.02	0.163	1

Figure 48: Density Cluster 3, Matrix of Correlation

r	S	K	Ca	Ti	Mn	Fe	Cu	Zn	Rb	Sr	Zr	Ba	Pb
S	1	-0.093	-0.126	0.356	0.009	0.545	0.165	0.104	0.02	-0.231	-0.106	0.314	0.273
K	-0.093	1	0.23	-0.094	0.331	-0.342	-0.194	-0.043	0.769	0.525	-0.048	0.047	-0.034
Ca	-0.126	0.23	1	-0.1	0.36	-0.158	0.11	0.253	0.04	0.602	-0.189	-0.026	0.039
Ti	0.356	-0.094	-0.1	1	0.322	0.68	0.112	-0.059	-0.147	-0.364	0.397	0.477	-0.13
Mn	0.009	0.331	0.36	0.322	1	0.167	0.229	0.039	0.162	0.003	0.107	0.342	-0.117
Fe	0.545	-0.342	-0.158	0.68	0.167	1	0.192	-0.06	-0.249	-0.453	0.021	0.706	-0.128
Cu	0.165	-0.194	0.11	0.112	0.229	0.192	1	-0.044	-0.25	-0.079	-0.018	0.235	0.208
Zn	0.104	-0.043	0.253	-0.059	0.039	-0.06	-0.044	1	-0.063	0.074	-0.043	-0.037	0.464
Rb	0.02	0.769	0.04	-0.147	0.162	-0.249	-0.25	-0.063	1	0.294	-0.102	0.013	-0.019
Sr	-0.231	0.525	0.602	-0.364	0.003	-0.453	-0.079	0.074	0.294	1	-0.231	-0.098	0.063
Zr	-0.106	-0.048	-0.189	0.397	0.107	0.021	-0.018	-0.043	-0.102	-0.231	1	0.022	0.07
Ba	0.314	0.047	-0.026	0.477	0.342	0.706	0.235	-0.037	0.013	-0.098	0.022	1	-0.094
Pb	0.273	-0.034	0.039	-0.13	-0.117	-0.128	0.208	0.464	-0.019	0.063	0.07	-0.094	1

Figure 49: Density Cluster 4, Matrix of Correlation

Correlation between lean and zinc within the 100-micron fraction is 0.582. The samples of the 100-micron soil fraction were divided into four grouping based on increasing population density and correlation matrixes calculated. The lead to zinc correlation matrixes are displayed in figures 46 through 49. With increase in population density throughout the city of Atlanta the correlation coefficients 0.73, 0.758, 0.95, and 0.464. The regions which are most heavily populated, in the urban core of the environment show the least correlation between lead and zinc. As the correlation coefficients between lead and zinc increased consistently throughout the first three clusters, the correlation coefficients between lead and sulfur changed more sporadically. The sulfur lead coefficient initially declined then increase as population density throughout the last three density clusters for the city of Atlanta. the correlation coefficients of lead and sulfur were -0.186, 0.157, 0.261, and 0.273. Density cluster two, Figure 47, is the only cluster to show significant correlations between lead, potassium, Strontium, and rubidium.

4.3.7 ICP-MS Analysis

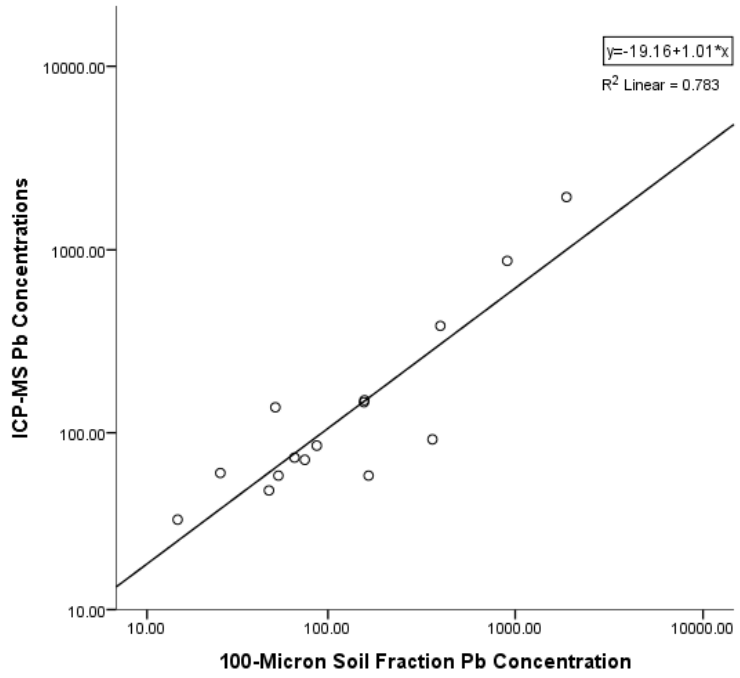

Figure 50: Scatter Plot ICP-MS and XRF of Lead

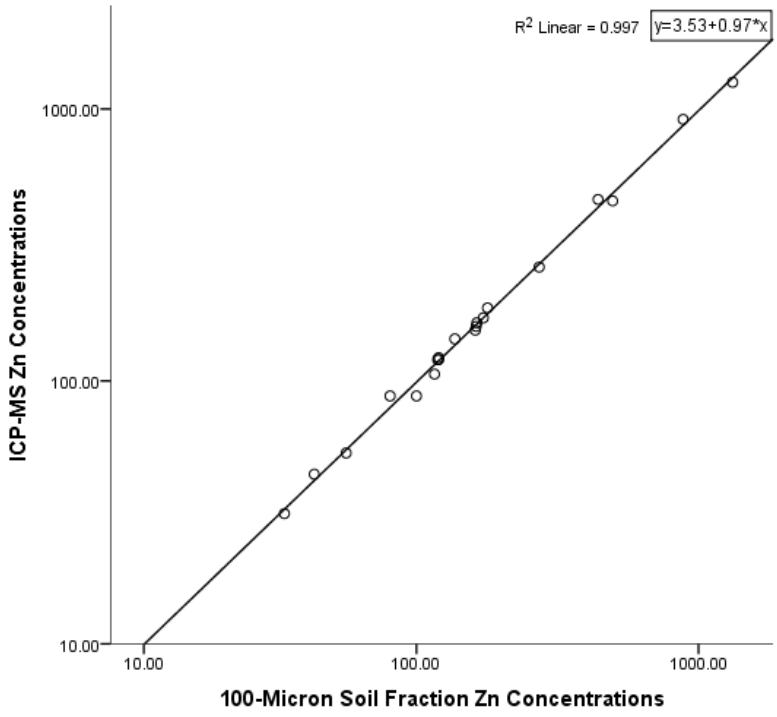

Figure 51: Scatter Plot ICP-MS and XRF of Zinc

FID	100 micro Pb	Bulk Sample Pb	ICP_MS Pb
11	1875	697	1940
219	907	562	871
183	399	411	385
226	362	1223	92
309	165	225	58
379	157	115	151
174	156	234	147
270	87	55	85
102	75	116	71
122	66	38	73
181	54	2467	58
360	52	163	138
268	48	76	48
1096	26	363	60
525	15	1874	33

Table 3: Comparison of Lead Concentrations between Bulk XRF, 100-Micron XRF, and ICP-MS

Inductively coupled plasma mass spectroscopy (ICP-MS) was used to analyzed twenty of the 100-micron soil sampled selected across the entire range of sample to confirm the accuracy of the results collected with the XRF. Table 3, displays the results of the ICP-MS analysis preformed at Actlabs in Ancaster, Ontario. The minimum concentration of lead found was 33 ppm and the maximum was 1940. To confirm the accuracy of the XRF, scatter plots and regression lines were generated to determine variation, figures 50 and 51. Figure 50 displays the results between the ICP-MS and 100-micron XRF for Lead and figure 51 displays the results for Zinc. These two elements were chosen based on the high correlation between the two elements in both the XRF and ICP-MS correlation matrixes. Figure 52 and 53 displays the correlation matrix for the ICP-MS data. The R^2 value between lead concentrations for ICP-MS and XRF was 0.783 meaning there is little deviation in results between techniques. Zinc expressed even less variation with a R^2 value of .997.

r	Li	Na	Mg	Al	K	Ca	Cd	V	Cr	Mn	Fe	Hf	Ni	Er	Be	Ho	Hg	Cs	Co	Eu	Bi	Se	Zn
Li	1.00	-0.10	0.64	0.50	0.35	0.10	0.15	0.33	0.10	0.40	0.60	0.14	0.45	0.38	0.55	0.32	0.03	0.54	0.67	0.35	0.05	0.18	0.21
Na	-0.10	1.00	-0.14	0.02	0.31	0.24	-0.13	-0.35	-0.22	0.14	-0.36	-0.34	-0.20	0.60	0.69	0.50	-0.04	0.35	-0.28	-0.23	0.47	0.00	-0.15
Mg	0.64	-0.14	1.00	0.38	0.09	0.61	-0.06	0.31	0.44	0.70	0.74	-0.13	0.70	0.28	0.28	0.35	0.13	-0.01	0.81	0.59	-0.19	-0.15	-0.02
Al	0.50	0.02	0.38	1.00	0.28	0.07	-0.03	0.05	0.08	0.08	0.33	0.04	0.18	0.42	0.33	0.36	-0.14	0.42	0.36	0.35	0.02	0.16	0.01
K	0.35	0.31	0.09	0.28	1.00	0.00	-0.04	-0.15	-0.33	0.07	-0.11	0.23	-0.09	0.39	0.53	0.28	-0.22	0.59	0.01	-0.03	0.28	0.23	0.01
Ca	0.10	0.24	0.61	0.07	0.00	1.00	0.19	-0.15	0.35	0.55	0.12	-0.43	0.33	0.22	0.24	0.27	0.30	-0.19	0.23	0.27	0.22	-0.19	0.18
Cd	0.15	-0.13	-0.06	-0.03	-0.04	0.19	1.00	-0.15	0.05	-0.05	-0.18	-0.39	-0.05	-0.04	0.03	-0.05	0.62	-0.05	-0.11	-0.01	0.57	0.41	0.98
V	0.33	-0.35	0.31	0.05	-0.15	-0.15	-0.15	1.00	0.63	0.55	0.67	0.38	0.62	-0.17	-0.05	-0.15	-0.09	0.07	0.64	0.09	-0.14	0.32	-0.15
Cr	0.10	-0.22	0.44	0.08	-0.33	0.35	0.05	0.63	1.00	0.69	0.60	-0.02	0.80	-0.17	-0.24	-0.06	0.13	-0.29	0.54	0.26	0.00	0.09	0.06
Mn	0.40	0.14	0.70	0.08	0.07	0.55	-0.05	0.55	0.69	1.00	0.70	-0.02	0.85	0.37	0.33	0.44	-0.02	0.03	0.76	0.45	0.07	0.15	-0.05
Fe	0.60	-0.36	0.74	0.33	-0.11	0.12	-0.18	0.67	0.60	0.70	1.00	0.24	0.87	0.27	0.06	0.35	-0.09	0.04	0.96	0.70	-0.37	0.08	-0.15
Hf	0.14	-0.34	-0.13	0.04	0.23	-0.43	-0.39	0.38	-0.02	-0.02	0.24	1.00	0.03	-0.15	-0.07	-0.20	-0.62	0.40	0.12	0.00	-0.23	0.34	-0.34
Ni	0.45	-0.20	0.70	0.18	-0.09	0.33	-0.05	0.62	0.80	0.85	0.87	0.03	1.00	0.22	0.05	0.34	0.00	-0.10	0.85	0.63	-0.10	0.16	-0.03
Er	0.38	0.60	0.28	0.42	0.39	0.22	-0.04	-0.17	-0.17	0.37	0.27	-0.15	0.22	1.00	0.72	0.96	-0.07	0.45	0.33	0.50	0.16	0.21	-0.05
Be	0.55	0.69	0.28	0.33	0.53	0.24	0.03	-0.05	-0.24	0.33	0.06	-0.07	0.05	0.72	1.00	0.58	-0.02	0.69	0.19	0.00	0.49	0.28	0.05
Ho	0.32	0.50	0.35	0.36	0.28	0.27	-0.05	-0.15	-0.06	0.44	0.35	-0.20	0.34	0.96	0.58	1.00	-0.04	0.23	0.40	0.66	0.06	0.19	-0.05
Hg	0.03	-0.04	0.13	-0.14	-0.22	0.30	0.62	-0.09	0.13	-0.02	-0.09	-0.62	0.00	-0.07	-0.02	-0.04	1.00	-0.29	-0.02	0.06	0.26	-0.04	0.63
Cs	0.54	0.35	-0.01	0.42	0.59	-0.19	-0.05	0.07	-0.29	0.03	0.04	0.40	-0.10	0.45	0.69	0.23	-0.29	1.00	0.09	-0.16	0.39	0.37	-0.02
Co	0.67	-0.28	0.81	0.36	0.01	0.23	-0.11	0.64	0.54	0.76	0.96	0.12	0.85	0.33	0.19	0.40	-0.02	0.09	1.00	0.68	-0.26	0.08	-0.09
Eu	0.35	-0.23	0.59	0.35	-0.03	0.27	-0.01	0.09	0.26	0.45	0.70	0.00	0.63	0.50	0.00	0.66	0.06	-0.16	0.68	1.00	-0.35	0.06	0.01
Bi	0.05	0.47	-0.19	0.02	0.28	0.22	0.57	-0.14	0.00	0.07	-0.37	-0.23	-0.10	0.16	0.49	0.06	0.26	0.39	-0.26	-0.35	1.00	0.55	0.59
e	0.18	0.00	-0.15	0.16	0.23	-0.19	0.41	0.32	0.09	0.15	0.08	0.34	0.16	0.21	0.28	0.19	-0.04	0.37	0.08	0.06	0.55	1.00	0.42
Zn	0.21	-0.15	-0.02	0.01	0.01	0.18	0.98	-0.15	0.06	-0.05	-0.15	-0.34	-0.03	-0.05	0.05	-0.05	0.63	-0.02	-0.09	0.01	0.59	0.42	1.00
Ga	0.68	0.21	0.35	0.35	0.47	-0.19	-0.18	0.43	0.08	0.45	0.53	0.38	0.40	0.55	0.67	0.47	-0.17	0.64	0.53	0.23	0.07	0.41	-0.13
Rb	0.14	0.79	-0.25	0.16	0.69	-0.02	0.03	-0.36	-0.49	-0.08	-0.41	-0.02	-0.35	0.58	0.80	0.43	-0.10	0.68	-0.31	-0.27	0.62	0.32	0.06
Y	0.18	0.70	0.15	0.26	0.30	0.23	-0.02	-0.29	-0.20	0.30	0.11	-0.27	0.12	0.96	0.67	0.95	0.01	0.29	0.17	0.43	0.20	0.20	-0.03
Zr	0.21	-0.40	-0.12	0.04	0.23	-0.43	-0.24	0.41	-0.01	-0.01	0.24	0.98	0.04	-0.17	-0.08	-0.22	-0.54	0.41	0.14	0.02	-0.19	0.42	-0.20
Nb	0.02	0.23	-0.04	0.09	0.12	-0.16	-0.16	0.60	0.38	0.31	0.08	0.09	0.21	-0.10	0.23	-0.16	-0.26	0.20	0.10	-0.44	0.34	0.31	-0.16
Mo	0.06	0.00	-0.09	-0.18	0.28	-0.13	0.16	0.47	0.10	0.22	-0.05	0.21	0.13	-0.18	0.20	-0.21	-0.14	0.19	0.05	-0.34	0.53	0.65	0.18
Sn	0.04	0.02	-0.05	0.29	0.19	-0.11	0.20	0.25	0.18	0.05	-0.04	0.05	0.08	-0.14	0.15	-0.21	-0.12	0.24	-0.01	-0.25	0.55	0.41	0.21
Ba	0.37	-0.36	0.29	0.21	0.42	0.10	0.47	0.00	0.00	0.11	0.20	0.06	0.12	0.09	-0.07	0.10	0.31	0.07	0.25	0.41	-0.08	0.17	0.49
La	0.01	-0.17	0.26	0.05	-0.25	0.11	-0.03	-0.12	0.12	0.20	0.40	-0.09	0.39	0.34	-0.22	0.56	0.00	-0.42	0.33	0.84	-0.40	0.02	-0.01
Ce	0.02	-0.19	0.31	0.05	-0.19	0.14	-0.02	-0.08	0.12	0.23	0.41	-0.12	0.39	0.34	-0.22	0.56	0.01	-0.45	0.37	0.84	-0.43	0.01	-0.01
Pr	0.01	-0.16	0.30	0.05	-0.24	0.15	-0.04	-0.09	0.14	0.25	0.43	-0.13	0.42	0.37	-0.21	0.59	0.01	-0.44	0.38	0.86	-0.41	0.00	-0.03
Nd	0.02	-0.17	0.33	0.07	-0.24	0.18	-0.03	-0.07	0.17	0.27	0.46	-0.13	0.44	0.38	-0.20	0.60	0.02	-0.44	0.40	0.87	-0.41	0.01	-0.02
Sm	0.01	-0.09	0.31	0.06	-0.20	0.19	-0.02	-0.06	0.18	0.31	0.45	-0.14	0.46	0.44	-0.14	0.66	0.02	-0.42	0.40	0.86	-0.36	0.06	-0.02
Gd	0.01	0.05	0.32	0.07	-0.16	0.25	-0.04	-0.09	0.16	0.36	0.41	-0.22	0.44	0.54	-0.03	0.74	0.03	-0.37	0.38	0.82	-0.29	0.06	-0.04
Tb	0.06	0.25	0.33	0.16	-0.04	0.29	-0.07	-0.11	0.12	0.41	0.39	-0.23	0.43	0.71	0.17	0.87	-0.01	-0.21	0.38	0.79	-0.19	0.10	-0.08
Dy	0.16	0.41	0.30	0.25	0.08	0.27	-0.06	-0.14	0.03	0.41	0.36	-0.24	0.37	0.86	0.37	0.96	-0.01	0.00	0.37	0.72	-0.06	0.16	-0.06
Cu	0.25	-0.20	0.52	0.22	-0.09	0.27	0.23	0.36	0.67	0.65	0.60	-0.11	0.76	0.12	0.00	0.22	0.20	-0.17	0.62	0.50	0.13	0.21	0.26
Tm	0.37	0.66	0.18	0.47	0.50	0.17	-0.06	-0.20	-0.22	0.30	0.16	-0.05	0.11	0.96	0.76	0.87	-0.17	0.60	0.22	0.37	0.23	0.22	-0.07
Yb	0.40	0.65	0.16	0.45	0.45	0.13	-0.02	-0.16	-0.26	0.28	0.14	-0.07	0.07	0.95	0.82	0.84	-0.10	0.65	0.22	0.29	0.28	0.27	-0.04
Lu	0.36	0.61	0.12	0.34	0.38	0.06	0.01	-0.21	-0.35	0.20	0.12	-0.10	0.00	0.94	0.78	0.84	-0.06	0.58	0.19	0.28	0.23	0.24	-0.01
Sr	0.14	0.01	0.22	0.33	0.31	0.37	0.23	-0.20	-0.03	0.10	0.04	-0.01	-0.04	0.26	0.05	0.26	0.24	0.13	0.12	0.39	0.02	-0.02	0.27
Ti	0.18	0.80	-0.24	0.14	0.56	0.01	0.16	-0.17	-0.33	0.05	-0.35	-0.07	-0.25	0.55	0.82	0.38	-0.04	0.69	-0.25	-0.34	0.74	0.43	0.16
Pb	0.16	-0.11	-0.13	-0.04	-0.03	0.08	0.99	-0.15	-0.02	-0.11	-0.22	-0.35	-0.12	-0.04	0.05	-0.06	0.60	0.00	-0.16	-0.05	0.57	0.45	0.97
Th	-0.17	0.15	0.05	-0.20	-0.13	0.12	0.12	-0.30	-0.03	0.11	0.05	-0.33	0.17	0.36	-0.07	0.56	0.06	-0.43	0.03	0.51	-0.10	0.11	0.11
U	-0.14	0.61	-0.37	-0.15	0.19	-0.13	0.15	-0.32	-0.35	-0.03	-0.31	-0.14	-0.21	0.55	0.39	0.55	-0.12	0.21	-0.29	0.00	0.36	0.41	0.13

Figure 52: ICP-MS Matrix of Correlation: Li, Na, Mg, Al, K, Ca, Cd, V, Cr, Mn, Fe, Hf, Ni, Er, Be, Ho, Hg, Cs, Co, Eu, Bi, Se, Zn

r	Ga	Rb	Y	Zr	Nb	Mo	Sn	Ba	La	Ce	Pr	Nd	Sm	Gd	Tb	Dy	Cu	Tm	Yb	Lu	Sr	Tl	Pb	Th	U
Li	0.68	0.14	0.18	0.21	0.02	0.06	0.04	0.37	0.01	0.02	0.01	0.02	0.01	0.01	0.06	0.16	0.25	0.37	0.40	0.36	0.14	0.18	0.16	-0.17	-0.14
Na	0.21	0.79	0.70	-0.40	0.23	0.00	0.02	-0.36	-0.17	-0.19	-0.16	-0.17	-0.09	0.05	0.25	0.41	-0.20	0.66	0.65	0.61	0.01	0.80	-0.11	0.15	0.61
Mg	0.35	-0.25	0.15	-0.12	-0.04	-0.09	-0.05	0.29	0.26	0.31	0.30	0.33	0.31	0.32	0.33	0.30	0.52	0.18	0.16	0.12	0.22	-0.24	-0.13	0.05	-0.37
Al	0.35	0.16	0.26	0.04	0.09	-0.18	0.29	0.21	0.05	0.05	0.05	0.07	0.06	0.07	0.16	0.25	0.22	0.47	0.45	0.34	0.33	0.14	-0.04	-0.20	-0.15
K	0.47	0.69	0.30	0.23	0.12	0.28	0.19	0.42	-0.25	-0.19	-0.24	-0.24	-0.20	-0.16	-0.04	0.08	-0.09	0.50	0.45	0.38	0.31	0.56	-0.03	-0.13	0.19
Ca	-0.19	-0.02	0.23	-0.43	-0.16	-0.13	-0.11	0.10	0.11	0.14	0.15	0.18	0.19	0.25	0.29	0.27	0.27	0.17	0.13	0.06	0.37	0.01	0.08	0.12	-0.13
Cd	-0.18	0.03	-0.02	-0.24	-0.16	0.16	0.20	0.47	-0.03	-0.02	-0.04	-0.03	-0.02	-0.04	-0.07	-0.06	0.23	-0.06	-0.02	0.01	0.23	0.16	0.99	0.12	0.15
V	0.43	-0.36	-0.29	0.41	0.60	0.47	0.25	0.00	-0.12	-0.08	-0.09	-0.07	-0.06	-0.09	-0.11	-0.14	0.36	-0.20	-0.16	-0.21	-0.20	-0.17	-0.15	-0.30	-0.32
Cr	0.08	-0.49	-0.20	-0.01	0.38	0.10	0.18	0.00	0.12	0.12	0.14	0.17	0.18	0.16	0.12	0.03	0.67	-0.22	-0.26	-0.35	-0.03	-0.33	-0.02	-0.03	-0.35
Mn	0.45	-0.08	0.30	-0.01	0.31	0.22	0.05	0.11	0.20	0.23	0.25	0.27	0.31	0.36	0.41	0.41	0.65	0.30	0.28	0.20	0.10	0.05	-0.11	0.11	-0.03
Fe	0.53	-0.41	0.11	0.24	0.08	-0.05	-0.04	0.20	0.40	0.41	0.43	0.46	0.45	0.41	0.39	0.36	0.60	0.16	0.14	0.12	0.04	-0.35	-0.22	0.05	-0.31
Hf	0.38	-0.02	-0.27	0.98	0.09	0.21	0.05	0.06	-0.09	-0.12	-0.13	-0.13	-0.14	-0.22	-0.23	-0.24	-0.11	-0.05	-0.07	-0.10	-0.01	-0.07	-0.35	-0.33	-0.14
Ni	0.40	-0.35	0.12	0.04	0.21	0.13	0.08	0.12	0.39	0.39	0.42	0.44	0.46	0.44	0.43	0.37	0.76	0.11	0.07	0.00	-0.04	-0.25	-0.12	0.17	-0.21
Er	0.55	0.58	0.96	-0.17	-0.10	-0.18	-0.14	0.09	0.34	0.34	0.37	0.38	0.44	0.54	0.71	0.86	0.12	0.96	0.95	0.94	0.26	0.55	-0.04	0.36	0.55
Be	0.67	0.80	0.67	-0.08	0.23	0.20	0.15	-0.07	-0.22	-0.22	-0.21	-0.20	-0.14	-0.03	0.17	0.37	0.00	0.76	0.82	0.78	0.05	0.82	0.05	-0.07	0.39
Ho	0.47	0.43	0.95	-0.22	-0.16	-0.21	-0.21	0.10	0.56	0.56	0.59	0.60	0.66	0.74	0.87	0.96	0.22	0.87	0.84	0.84	0.26	0.38	-0.06	0.56	0.55
Hg	-0.17	-0.10	0.01	-0.54	-0.26	-0.14	-0.12	0.31	0.00	0.01	0.01	0.02	0.02	0.03	-0.01	-0.01	0.20	-0.17	-0.10	-0.06	0.24	-0.04	0.60	0.06	-0.12
Cs	0.64	0.68	0.29	0.41	0.20	0.19	0.24	0.07	-0.42	-0.45	-0.44	-0.44	-0.42	-0.37	-0.21	0.00	-0.17	0.60	0.65	0.58	0.13	0.69	0.00	-0.43	0.21
Co	0.53	-0.31	0.17	0.14	0.10	0.05	-0.01	0.25	0.33	0.37	0.38	0.40	0.40	0.38	0.38	0.37	0.62	0.22	0.22	0.19	0.12	-0.25	-0.16	0.03	-0.29
Eu	0.23	-0.27	0.43	0.02	-0.44	-0.34	-0.25	0.41	0.84	0.84	0.86	0.87	0.86	0.82	0.79	0.72	0.50	0.37	0.29	0.28	0.39	-0.34	-0.05	0.51	0.00
Bi	0.07	0.62	0.20	-0.19	0.34	0.53	0.55	-0.08	-0.40	-0.43	-0.41	-0.41	-0.36	-0.29	-0.19	-0.06	0.13	0.23	0.28	0.23	0.02	0.74	0.57	-0.10	0.36
e	0.41	0.32	0.20	0.42	0.31	0.65	0.41	0.17	0.02	0.01	0.00	0.01	0.06	0.06	0.10	0.16	0.21	0.22	0.27	0.24	-0.02	0.43	0.45	0.11	0.41
Zn	-0.13	0.06	-0.03	-0.20	-0.16	0.18	0.21	0.49	-0.01	-0.01	-0.03	-0.02	-0.02	-0.04	-0.08	-0.06	0.26	-0.07	-0.04	-0.01	0.27	0.16	0.97	0.11	0.13
Ga	1.00	0.41	0.43	0.38	0.31	0.21	0.10	0.12	-0.04	-0.04	-0.04	-0.03	0.02	0.06	0.19	0.31	0.27	0.55	0.61	0.58	-0.09	0.43	-0.13	-0.10	0.17
Rb	0.41	1.00	0.61	-0.05	0.19	0.23	0.19	-0.10	-0.31	-0.33	-0.33	-0.34	-0.27	-0.16	0.03	0.23	-0.26	0.69	0.71	0.67	0.10	0.95	0.07	-0.03	0.59
Y	0.43	0.61	1.00	-0.29	-0.12	-0.18	-0.20	-0.02	0.41	0.40	0.43	0.44	0.51	0.62	0.77	0.90	0.07	0.89	0.88	0.89	0.21	0.56	-0.01	0.53	0.69
Zr	0.38	-0.05	-0.29	1.00	0.06	0.25	0.05	0.19	-0.07	-0.09	-0.11	-0.11	-0.13	-0.22	-0.24	-0.26	-0.08	-0.07	-0.09	-0.12	0.04	-0.07	-0.19	-0.30	-0.11
Nb	0.31	0.19	-0.12	0.06	1.00	0.67	0.68	-0.39	-0.51	-0.47	-0.47	-0.47	-0.42	-0.37	-0.28	-0.22	0.13	-0.03	-0.01	-0.08	-0.42	0.36	-0.14	-0.33	0.00
Mo	0.21	0.23	-0.18	0.25	0.67	1.00	0.60	-0.08	-0.35	-0.30	-0.34	-0.34	-0.30	-0.29	-0.29	-0.26	0.13	-0.16	-0.11	-0.15	-0.27	0.35	0.18	-0.14	0.15
Sn	0.10	0.19	-0.20	0.05	0.68	0.60	1.00	-0.13	-0.41	-0.42	-0.40	-0.41	-0.40	-0.40	-0.35	-0.29	0.33	-0.01	-0.03	-0.10	-0.18	0.30	0.19	-0.37	-0.13
Ba	0.12	-0.10	-0.02	0.19	-0.39	-0.08	-0.13	1.00	0.22	0.29	0.22	0.24	0.21	0.14	0.09	0.06	0.23	0.10	0.05	0.01	0.68	-0.14	0.47	0.06	-0.09
La	-0.04	-0.31	0.41	-0.07	-0.51	-0.35	-0.41	0.22	1.00	0.98	0.99	0.99	0.98	0.94	0.85	0.73	0.28	0.18	0.08	0.13	0.24	-0.40	-0.04	0.82	0.30
Ce	-0.04	-0.33	0.40	-0.09	-0.47	-0.30	-0.42	0.29	0.98	1.00	0.99	0.99	0.98	0.95	0.86	0.73	0.26	0.17	0.07	0.13	0.27	-0.42	-0.03	0.84	0.30
Pr	-0.04	-0.33	0.43	-0.11	-0.47	-0.34	-0.40	0.22	0.99	0.99	1.00	1.00	0.99	0.96	0.88	0.76	0.29	0.21	0.10	0.15	0.23	-0.41	-0.06	0.83	0.29
Nd	-0.03	-0.34	0.44	-0.11	-0.47	-0.34	-0.41	0.24	0.99	0.99	1.00	1.00	0.99	0.96	0.89	0.77	0.31	0.21	0.11	0.16	0.25	-0.41	-0.05	0.82	0.27
Sm	0.02	-0.27	0.51	-0.13	-0.42	-0.30	-0.40	0.21	0.98	0.98	0.99	0.99	1.00	0.99	0.93	0.82	0.32	0.27	0.17	0.22	0.23	-0.34	-0.05	0.85	0.33
Gd	0.06	-0.16	0.62	-0.22	-0.37	-0.29	-0.40	0.14	0.94	0.95	0.96	0.96	0.99	1.00	0.97	0.89	0.29	0.36	0.28	0.33	0.21	-0.23	-0.06	0.87	0.42
Tb	0.19	0.03	0.77	-0.24	-0.28	-0.29	-0.35	0.09	0.85	0.86	0.88	0.89	0.93	0.97	1.00	0.97	0.26	0.56	0.48	0.51	0.21	-0.02	-0.09	0.82	0.50
Dy	0.31	0.23	0.90	-0.26	-0.22	-0.26	-0.29	0.06	0.73	0.73	0.76	0.77	0.82	0.89	0.97	1.00	0.22	0.73	0.67	0.70	0.23	0.19	-0.07	0.73	0.58
Cu	0.27	-0.26	0.07	-0.08	0.13	0.13	0.33	0.23	0.28	0.26	0.29	0.31	0.32	0.29	0.26	0.22	1.00	0.03	0.04	-0.01	0.08	-0.19	0.17	0.07	-0.22
Tm	0.55	0.69	0.89	-0.07	-0.03	-0.16	-0.01	0.10	0.18	0.17	0.21	0.21	0.27	0.36	0.56	0.73	0.03	1.00	0.97	0.93	0.32	0.66	-0.05	0.20	0.54
Yb	0.61	0.71	0.88	-0.09	-0.01	-0.11	-0.03	0.05	0.08	0.07	0.10	0.11	0.17	0.28	0.48	0.67	0.04	0.97	1.00	0.97	0.22	0.70	0.00	0.12	0.52
Lu	0.58	0.67	0.89	-0.12	-0.08	-0.15	-0.10	0.01	0.13	0.13	0.15	0.16	0.22	0.33	0.51	0.70	-0.01	0.93	0.97	1.00	0.14	0.65	0.03	0.21	0.57
Sr	-0.09	0.10	0.21	0.04	-0.42	-0.27	-0.18	0.68	0.24	0.27	0.23	0.25	0.23	0.21	0.21	0.23	0.08	0.32	0.22	0.14	1.00	0.02	0.20	0.03	0.03
Ti	0.43	0.95	0.56	-0.07	0.36	0.35	0.30	-0.14	-0.40	-0.42	-0.41	-0.41	-0.34	-0.23	-0.02	0.19	-0.19	0.66	0.70	0.65	0.02	1.00	0.20	-0.10	0.59
Pb	-0.13	0.07	-0.01	-0.19	-0.14	0.18	0.19	0.47	-0.04	-0.03	-0.06	-0.05	-0.05	-0.06	-0.09	-0.07	0.17	-0.05	0.00	0.03	0.20	0.20	1.00	0.11	0.21
Th	-0.10	-0.03	0.53	-0.30	-0.33	-0.14	-0.37	0.06	0.82	0.84	0.83	0.82	0.85	0.87	0.82	0.73	0.07	0.20	0.12	0.21	0.03	-0.10	0.11	1.00	0.63
U	0.17	0.59	0.69	-0.11	0.00	0.15	-0.13	-0.09	0.30	0.30	0.29	0.27	0.33	0.42	0.50	0.58	-0.22	0.54	0.52	0.57	0.03	0.59	0.21	0.63	1.00

Figure 53: Matrix of Correlation: Ga, Rb, Y, Zr, Nb, Mo, Sn, Ba, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Cu, Tm, Yb, Lu, Sr, Ti, Pb, Th, U

4.3.8 Factor Analysis: Principal Component Analysis

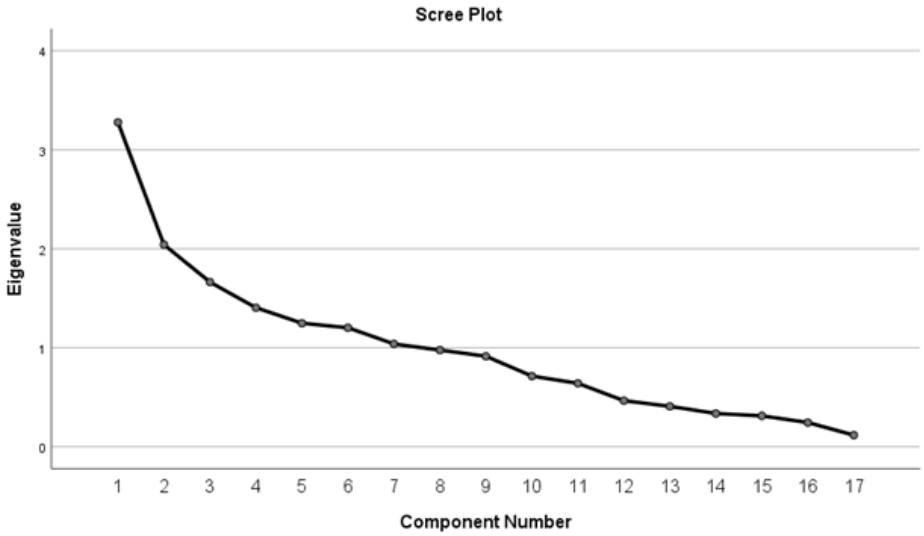

Figure 54: Scree Plot of 100-Micron soil Fraction XRF Results

Figure 54, is the scree plot generated within SPSS as a first step in beginning the principal component analysis (PCA) for factor reduction. The figure illustrates the seven-teen possible factors in the PCA and aides in determining the appropriate number of factors to limit the analysis. By only considering the first seven factors, which have an eigenvalue greater than one we are able to simplify the result to determine unique trends within the entire data set of elemental concentrations. Concentrations were determined through handheld Xray fluorescence of the 100-micron soil fraction. Only the first seven factors were used in the PCA since they account for a major of the variance within the dataset.

	Mean	Std. Deviation	Analysis N
S	9506.894	5327.609	1133
K	17256.22	5162.885	1133
Ca	4298.699	4411.553	1133
Ti	6980.094	3250.384	1133
Cr	32.8235	29.91092	1133
Mn	676.188	319.6227	1133
Fe	41349.38	15292.65	1133
Co	108.3698	95.48624	1133
Cu	37.6752	41.33038	1133
Zn	178.7846	335.0846	1133
As	6.4607	2.77188	1133
Rb	103.4369	39.74142	1133
Sr	61.8385	40.41985	1133
Zr	655.0883	387.7722	1133
Cd	27.1836	6.58861	1133
Ba	371.0671	135.644	1133
Pb	132.677	299.6716	1133

Table 4: 100-Micron Soil Fraction Descriptive Statistics of XRF Results

Table 4 displays the mean values of soil concentrations within the 100-micron fraction as well as the corresponding standard deviations. One thousand one hundred and thirty-three individual concentrations were used to calculate the averages and were generated from handheld Xray fluorescence analysis. The large standard deviations with respect to the mean values can be attributed to the large range of values which were generated through the analysis of the soil throughout the urban environment. Lead has a mean concentration of 133ppm with a standard deviation of 299. Because the concentrations cannot be less than zero, this suggests the values are positively skewed or the data set contains large outliers.

Correlation Matrix

		S	K	Ca	Ti	Cr	Mn	Fe	Co	Cu
Correlation	S	1	-0.099	-0.051	0.403	0.048	0.185	0.663	-0.027	0.127
	K	-0.099	1	0.06	-0.165	-0.111	0.045	-0.1	-0.002	-0.005
	Ca	-0.051	0.06	1	-0.191	0.015	0.171	-0.066	-0.005	0.072
	Ti	0.403	-0.165	-0.191	1	0.172	0.343	0.639	0.1	0.144
	Cr	0.048	-0.111	0.015	0.172	1	0.103	0.162	0.097	0.217
	Mn	0.185	0.045	0.171	0.343	0.103	1	0.34	0.341	0.257
	Fe	0.663	-0.1	-0.066	0.639	0.162	0.34	1	0.059	0.234
	Co	-0.027	-0.002	-0.005	0.1	0.097	0.341	0.059	1	0.18
	Cu	0.127	-0.005	0.072	0.144	0.217	0.257	0.234	0.18	1
	Zn	0.095	0.003	0.242	0.013	0.031	0.088	0.029	-0.008	0.112
	As	-0.023	-0.101	0.017	0.076	0.014	0.052	-0.013	-0.023	-0.012
	Rb	-0.137	0.704	-0.06	-0.211	-0.115	-0.021	-0.206	-0.124	-0.087
	Sr	-0.202	0.329	0.473	-0.247	0.051	-0.064	-0.251	-0.02	-0.001
	Zr	-0.019	-0.132	-0.162	0.52	0.091	0.059	-0.005	0.025	-0.01
	Cd	-0.007	-0.015	-0.039	0.036	0.001	-0.029	0.016	-0.025	-0.01
	Ba	0.441	0.056	-0.061	0.465	0.301	0.239	0.655	-0.056	0.249
	Pb	0.131	0.014	0.132	0.005	0.005	0.013	-0.019	0.001	0.161

Table 5: Principal Components Analysis, Correlation Matrix Results for S, K, Ca, Ti, Cr, Mn, Fe, Co, Cu

		Zn	As	Rb	Sr	Zr	Cd	Ba	Pb
Correlation	S	0.095	-0.023	-0.137	-0.202	-0.019	-0.007	0.441	0.131
	K	0.003	-0.101	0.704	0.329	-0.132	-0.015	0.056	0.014
	Ca	0.242	0.017	-0.06	0.473	-0.162	-0.039	-0.061	0.132
	Ti	0.013	0.076	-0.211	-0.247	0.52	0.036	0.465	0.005
	Cr	0.031	0.014	-0.115	0.051	0.091	0.001	0.301	0.005
	Mn	0.088	0.052	-0.021	-0.064	0.059	-0.029	0.239	0.013
	Fe	0.029	-0.013	-0.206	-0.251	-0.005	0.016	0.655	-0.019
	Co	-0.008	-0.023	-0.124	-0.02	0.025	-0.025	-0.056	0.001
	Cu	0.112	-0.012	-0.087	-0.001	-0.01	-0.01	0.249	0.161
	Zn	1	-0.019	-0.027	0.084	-0.011	-0.026	0.058	0.582
	As	-0.019	1	-0.057	-0.008	0.106	0.001	0.024	-0.033
	Rb	-0.027	-0.057	1	0.141	-0.166	0.033	-0.056	0.013
	Sr	0.084	-0.008	0.141	1	-0.109	-0.032	0.059	0.067
	Zr	-0.011	0.106	-0.166	-0.109	1	0.059	0.152	0.037
	Cd	-0.026	0.001	0.033	-0.032	0.059	1	0.033	-0.022
	Ba	0.058	0.024	-0.056	0.059	0.152	0.033	1	0.058
	Pb	0.582	-0.033	0.013	0.067	0.037	-0.022	0.058	1

Table 6: Principal Components Analysis, Correlation Matrix Results for Zn, As, Rb, Sr, Zr, Cd, Ba, Pb

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.573
Bartlett's Test of Sphericity	Approx. Chi-Square	5831.038
	df	136
	Sig.	0

Table 7: KMO and Barlet's Test Results

Tables 5 and 6 represent the combined correlation coefficient, r, results of the principal component analysis (PCA) generated within SPSS. PCA was utilized to determine the correlation between the elemental concentration result of the XRF results of the 100-micron soil fraction. The PCA analysis was performed utilizing varying numbers of factors from the seven determined appropriate by the scree plot to determine the stability of the factor loading. These seven factors

determine nearly 70% the variance between samples as indicated in Table 8. Table 7 displays the Kaiser-Meyer-Olkin (KMO) and Bartlett's test used to test the adequacy of sampling used for the PCA. A KMO test result was 0.573 indicating adequate sampling size. Bartlett's test value of zero indicates the dataset is suitable for structure analysis and the factor reduction analysis through PCA.

Within Tables 5 and 6, there are numerous correlation coefficients which indicate a strong correlation between the pairs of elemental concentrations analyzed through the XRF within the fine grain soil fraction. The strongest of the correlations are between Iron and Titanium, Iron and Barium, Iron and Sulphur, and Potassium and Rubidium. The correlation coefficients are 0.639, 0.655, 0.663, and 0.704 respectably. Zinc and lead have a correlation coefficient of 0.582.

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.277	19.278	19.278	3.277	19.278	19.278
2	2.041	12.007	31.285	2.041	12.007	31.285
3	1.663	9.783	41.068	1.663	9.783	41.068
4	1.404	8.26	49.328	1.404	8.26	49.328
5	1.248	7.34	56.668	1.248	7.34	56.668
6	1.202	7.07	63.738	1.202	7.07	63.738
7	1.039	6.109	69.847	1.039	6.109	69.847
8	0.976	5.743	75.59			
9	0.914	5.376	80.966			
10	0.714	4.198	85.164			
11	0.641	3.768	88.932			
12	0.465	2.737	91.67			
13	0.408	2.398	94.068			
14	0.336	1.975	96.043			
15	0.312	1.834	97.877			
16	0.244	1.435	99.312			
17	0.117	0.688	100			

Table 8: Total Explained Variance, 100-Micron Fraction XRF Results

Reproduced Correlations									
		S	K	Ca	Ti	Cr	Mn	Fe	Co
Reproduced Correlation	S	.726[a]	-0.114	-0.061	0.451	0	0.233	0.747	-0.122
	K	-0.114	.861[a]	0.058	-0.165	-0.131	0.109	-0.118	-0.021
	Ca	-0.061	0.058	.729[a]	-0.251	0.059	0.163	-0.09	0.018
	Ti	0.451	-0.165	-0.251	.797[a]	0.201	0.384	0.618	0.111
	Cr	0	-0.131	0.059	0.201	.652[a]	0.062	0.177	0.109
	Mn	0.233	0.109	0.163	0.384	0.062	.698[a]	0.391	0.531
	Fe	0.747	-0.118	-0.09	0.618	0.177	0.391	.877[a]	0.02
	Co	-0.122	-0.021	0.018	0.111	0.109	0.531	0.02	.712[a]
	Cu	0.145	-0.007	0.106	0.177	0.39	0.337	0.268	0.355
	Zn	0.144	-0.005	0.283	0.014	-0.031	0.074	0.006	-0.02
	As	-0.044	-0.108	0.181	0.217	-0.127	0.131	-0.015	-0.049
	Rb	-0.151	0.814	-0.095	-0.207	-0.219	-0.03	-0.198	-0.097
	Sr	-0.261	0.353	0.591	-0.31	0.182	-0.017	-0.255	-0.123
	Zr	-0.091	-0.153	-0.259	0.535	0.175	0.078	0.014	0.039
	Cd	-0.069	0.03	-0.188	0.074	0.189	-0.155	-0.038	-0.097
	Ba	0.537	0.083	0.009	0.554	0.379	0.252	0.687	-0.12
	Pb	0.124	0.021	0.17	0.024	-0.024	0.022	-0.02	-0.032
Residual[b]	S		0.015	0.011	-0.048	0.048	-0.048	-0.084	0.095
	K	0.015		0.003	-8.52E-05	0.019	-0.064	0.017	0.02
	Ca	0.011	0.003		0.059	-0.044	0.008	0.024	-0.023
	Ti	-0.048	-8.52E-05	0.059		-0.029	-0.041	0.021	-0.011
	Cr	0.048	0.019	-0.044	-0.029		0.041	-0.015	-0.012
	Mn	-0.048	-0.064	0.008	-0.041	0.041		-0.05	-0.19
	Fe	-0.084	0.017	0.024	0.021	-0.015	-0.05		0.039
	Co	0.095	0.02	-0.023	-0.011	-0.012	-0.19	0.039	
	Cu	-0.018	0.002	-0.035	-0.032	-0.173	-0.08	-0.034	-0.175
	Zn	-0.049	0.008	-0.042	0	0.062	0.014	0.023	0.011
	As	0.021	0.007	-0.164	-0.142	0.142	-0.079	0.002	0.025
	Rb	0.014	-0.11	0.036	-0.004	0.104	0.009	-0.008	-0.027
	Sr	0.059	-0.024	-0.117	0.063	-0.131	-0.047	0.005	0.103
	Zr	0.072	0.021	0.097	-0.015	-0.084	-0.019	-0.018	-0.014
	Cd	0.061	-0.045	0.15	-0.037	-0.188	0.126	0.054	0.071
	Ba	-0.096	-0.027	-0.07	-0.089	-0.078	-0.013	-0.032	0.064
	Pb	0.007	-0.007	-0.039	-0.019	0.029	-0.009	0.001	0.032

Table 9: Reproduced Correlation and Residual, 100-Micron Fraction XRF for S, K, Ca, Ti, Cr, Mn, Fe, Co

Reproduced Correlations									
		Cu	Zn	As	Rb	Sr	Zr	Cd	Ba
Reproduced Correlation	S	0.145	0.144	-0.044	-0.151	-0.261	-0.091	-0.069	0.537
	K	-0.007	-0.005	-0.108	0.814	0.353	-0.153	0.03	0.083
	Ca	0.106	0.283	0.181	-0.095	0.591	-0.259	-0.188	0.009
	Ti	0.177	0.014	0.217	-0.207	-0.31	0.535	0.074	0.554
	Cr	0.39	-0.031	-0.127	-0.219	0.182	0.175	0.189	0.379
	Mn	0.337	0.074	0.131	-0.03	-0.017	0.078	-0.155	0.252
	Fe	0.268	0.006	-0.015	-0.198	-0.255	0.014	-0.038	0.687
	Co	0.355	-0.02	-0.049	-0.097	-0.123	0.039	-0.097	-0.12
	Cu	.480[a]	0.185	-0.207	-0.11	0.046	-0.025	0.029	0.278
	Zn	0.185	.763[a]	-0.041	-0.038	0.113	0.036	-0.04	0.047
	As	-0.207	-0.041	.492[a]	-0.145	0.119	0.331	-0.086	0.011
	Rb	-0.11	-0.038	-0.145	.827[a]	0.221	-0.13	0.063	-0.022
	Sr	0.046	0.113	0.119	0.221	.740[a]	-0.147	-0.022	0.059
	Zr	-0.025	0.036	0.331	-0.13	-0.147	.791[a]	0.183	0.163
	Cd	0.029	-0.04	-0.086	0.063	-0.022	0.183	.169[a]	0.097
	Ba	0.278	0.047	0.011	-0.022	0.059	0.163	0.097	.764[a]
	Pb	0.183	0.766	-0.102	0.015	0.045	0.08	0.01	0.036
Residual[b]	S	-0.018	-0.049	0.021	0.014	0.059	0.072	0.061	-0.096
	K	0.002	0.008	0.007	-0.11	-0.024	0.021	-0.045	-0.027
	Ca	-0.035	-0.042	-0.164	0.036	-0.117	0.097	0.15	-0.07
	Ti	-0.032	0	-0.142	-0.004	0.063	-0.015	-0.037	-0.089
	Cr	-0.173	0.062	0.142	0.104	-0.131	-0.084	-0.188	-0.078
	Mn	-0.08	0.014	-0.079	0.009	-0.047	-0.019	0.126	-0.013
	Fe	-0.034	0.023	0.002	-0.008	0.005	-0.018	0.054	-0.032
	Co	-0.175	0.011	0.025	-0.027	0.103	-0.014	0.071	0.064
	Cu		-0.073	0.195	0.023	-0.047	0.014	-0.038	-0.029
	Zn	-0.073		0.022	0.01	-0.03	-0.046	0.014	0.011
	As	0.195	0.022		0.088	-0.127	-0.226	0.087	0.013
	Rb	0.023	0.01	0.088		-0.079	-0.037	-0.03	-0.034
	Sr	-0.047	-0.03	-0.127	-0.079		0.038	-0.011	0
	Zr	0.014	-0.046	-0.226	-0.037	0.038		-0.124	-0.011
	Cd	-0.038	0.014	0.087	-0.03	-0.011	-0.124		-0.064
	Ba	-0.029	0.011	0.013	-0.034	0	-0.011	-0.064	
	Pb	-0.022	-0.184	0.069	-0.002	0.022	-0.043	-0.032	0.023

Table 10: Reproduced Correlation and Residual, 100-Micron Fraction XRF for Cu, Zn, As, Rb, Sr, Zr, Cd, Ba

Reproduced Correlations		
		Pb
Reproduced Correlation	S	0.124
	K	0.021
	Ca	0.17
	Ti	0.024
	Cr	-0.024
	Mn	0.022
	Fe	-0.02
	Co	-0.032
	Cu	0.183
	Zn	0.766
	As	-0.102
	Rb	0.015
	Sr	0.045
	Zr	0.08
	Cd	0.01
	Ba	0.036
	Pb	.796[a]
Residual[b]	S	0.007
	K	-0.007
	Ca	-0.039
	Ti	-0.019
	Cr	0.029
	Mn	-0.009
	Fe	0.001
	Co	0.032
	Cu	-0.022
	Zn	-0.184
	As	0.069
	Rb	-0.002
	Sr	0.022
	Zr	-0.043
	Cd	-0.032
	Ba	0.023
	Pb	

Table 11: Reproduced Correlation and Residual, 100-Micron Fraction XRF for Lead

Tables 9 through 11 display the results of the residual correlation matrix analysis generated in unison with the PCA. A residual matrix displays how closely the estimated factor analysis reproduces the observed correlation matrix. The observed correlation matrix displays the correlation between the various elements analyzed through the fine grain XRF procedure. An exact reproduction of values between the observed and the reproduction would result in a residual matrix entirely of zeros. The minimum and maximum values represent the greatest variation between the reproduced values and the observed values measured from the discrete samples collected. The reproduced correlation coefficient between lead and zinc was 0.766, resulting in a residual value of -0.184.

5 DISCUSSION

5.1 Samples Locations and Collection

Collecting soil samples within a densely populated and extensively developed urban environment has multiple limitations: site accessibility, soil mixing, and the vast size of the region. Upon consulting, Gabe Filippelli who has conducted numerous soil lead surveys within cities across the country, eight-hundred samples were collected to serve as a preliminary survey of the Atlanta soil lead enrichment. The semivariograms indicate the distance between samples within the study was too great to allow for accurate prediction of soil lead enrichment, but areas, where multiple highly enriched samples were found, should be reevaluated before areas of low enrichment. Many of the samples were collected near the roads due to the amount of development and accessibility. Often the highest concentrations of lead in the soil exist near the road, but low concentrations can also occur. Low concentrations may be a result of recent construction or roads which did not exist while leaded gasoline was in use. There was not a significant difference in median lead concentrations nor range between the various distances from roads among the samples.

5.2 Geochemical Analysis

Principal component analysis of the Xray fluorescence results of the 100-micron soil fraction allows for understanding the source and distribution of soil lead concentration with the urban environment. The amount of data gathered through Xray fluorescence makes finding relationships between the various components difficult. By reducing the number of factors and determining the correlation coefficients between each element the source of the enrichment. Strong positive correlations between Pb, Cd, Cu, Mo, and Zn suggest the enrichment is from vehicular traffic. The zinc enrichment is the result of the corrosion of engine parts, tires, and

its use in lubricating oils (Wang et al., 2005). Table 2 displays the strongest correlations found with the sample, one of which this between lead and zinc of 0.582. There are mild correlations between lead and copper, which may be a result Wang et al. (2005) attributed to the wear of engine components. Sulfur correlations to lead the same as copper. Figure 45 displays the strong positive correlation between increased population density and increased soil lead concentrations. The relationship is due to traffic intensity increasing as the region's population increases. The refinery process of Galena in the smelting process of steel production explains the correlation between lead and Sulphur. The weak correlation is likely a result of the extended period since smelting actively took place within the city and the high mobility of Sulphur within oxidizing environments.

Consistency in median soil lead concentration across the various bedrock types suggests the lead is not sourced from the weathering process of the bedrock. Since the mineralogy of the rock types vary if the lead was sourced from the weathering process then we would see a difference among rock types. Since the bedrock does not correlate to the concentration of soil lead it was unlikely the soil types would. Urban soils have a greater range in concentration and a large median value compared to the other soil types. Mixing outside sources and local point source contaminations cause the large range of the urban soil as well as the extreme heterogeneity. High outlier values a response to anthropogenic point sources. Consider the mineralogy of the soil series and the lack of lead-bearing minerals indicating the increased concentrations are from the anthropogenic lead.

Land with the highest intensity of development has lower median lead contamination likely due to increased flushing of surface sediments from overland flow. Since the lead partitions within the fine grain fraction of the soil, it becomes mobile because of overland flow caused

by the extensive coverage of the impermeable surface. Forested regions become enriched from the deposition of atmospheric lead particles from smelting activities and extensive transport of fine lead particles released from traffic sources.

5.3 Comparison of Atlanta Soil Contamination and Atlanta Road Dust Contamination

Atlanta road dust was collected and analyzed for lead concentrations by Dan Deocampo in 2012 for the downtown region and the residential region south of Interstate 20 (Deocampo et al., 2012). The road dust fraction are particles collected within the street less than 250 microns in diameter. Median road dust concentration for the downtown region were 63ppm with a maximum value of 278. Within the residential region concentrations had a median value of 93ppm with a maximum value of 972. Bulk soil sample lead concentrations are within the predicted values generated from IDW in the road dust study shown in fig 55 for the downtown region and fig 56 for the residential zone. The fine grain soil fraction of 100 microns had a median value of 75ppm and a maximum concentration of 3029. The increased range of values found within the urban soil compared to the road dust is likely a result of greater retention of lead within soils whose organic, oxide, and clay contents are greater (Laidlaw et al., 2012). The correlation coefficients between lead and zinc of .758 for density cluster 3 and .73 for density cluster 2 we very similar to the correlation found in downtown and residential setting, which were .72 and .79 respectively.

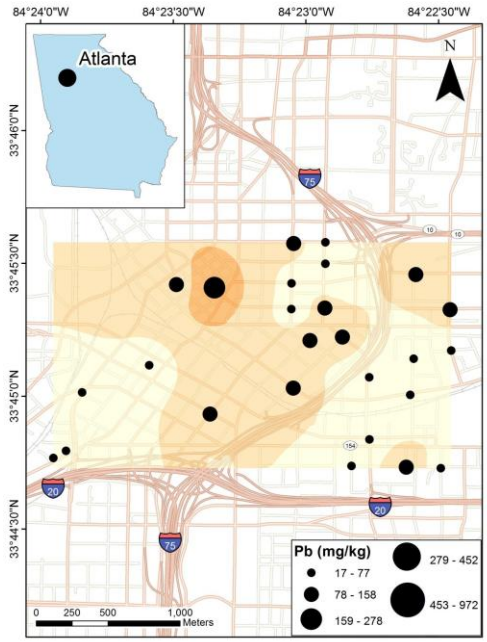

Figure 55: Inverse Distance Weighting, Downtown Atlanta Road Dust (Deocampoet al., 2012)

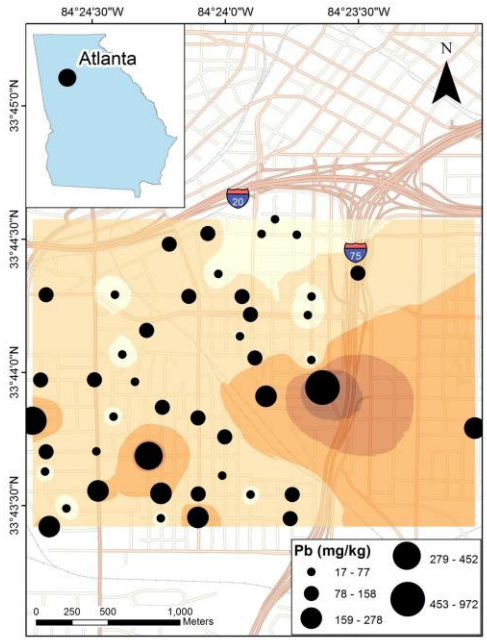

Figure 56: Inverse Distance Weighting, Residential Neighborhood (Deocampo et al., 2012)

5.4 Comparison of Atlanta Soil Lead Contamination and New Orleans Contamination

Howard Mielke et al. (2017) calculated soil lead concentrations within New Orleans pre and post hurricane Katrina and found the enrichment was depleted after the hurricane (Mielke, 2017). Figure 57 is the map of interpolated values for the region, generated through kriging. The initial lead enrichment had a minimum of 11ppm and maximum of 1789 ppm. The enrichment after Katrina had a minimum of 10ppm and maximum of 1076. The average concentration dropped from 289ppm to 143 ppm. The New Orleans study found that the greatest contributing factor to soil lead enrichment was tetra ethyl lead additives to gasoline, with greatest enrichment in the inner urban core of the city (Mielke, 2017). This pattern of distribution is the same found within the Atlanta urban environment. There range of enrichment is similar for Atlanta's urban environment, but the area of New Orleans is significantly smaller. Correlation between soil lead and soil zinc within Atlanta and New Orleans express similar strong trends within the urban environments. Mielke et al. found that the coexistent in soil between zinc and lead increases the risk of exposure to the populations because of reduced vegetative growth.

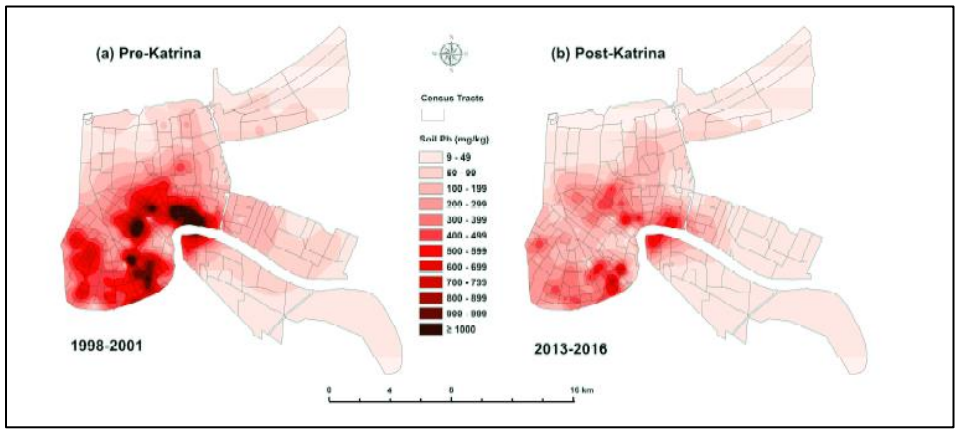

Figure 57: Map of Pre and Post Katrina Soil Lead Contamination in New Orleans (Mielke, 2017)

5.5 Comparison of Atlanta Soil Lead Contamination and Indianapolis Contamination

Deborah Morrison et al. tested soil samples throughout the WESCO neighborhood of Indianapolis due test for correlation between soil lead enrichment and elevated blood lead levels within children (Morrison et al., 2012). The study concluded the elevated blood lead levels did not correlate to soil enrichment at the 100m scale, but they were able to determine the both were a result of previous lead industry located in the neighborhood. The average soil lead concentration was 259 ppm, which is quite higher than the average found within the Atlanta region. Multiple samples around the Avanti Super Fund site, which were not remediated showed extreme enrichment with the highest concentration being 8119 ppm. Figure 58, displayed the inverse distance weighting preformed to interpolate values between the 263 collected samples throughout WESCO. Compared to Atlanta or New Orleans enrichment, Indianapolis appears to source from previous industrial activities in the southern portion of the study region.

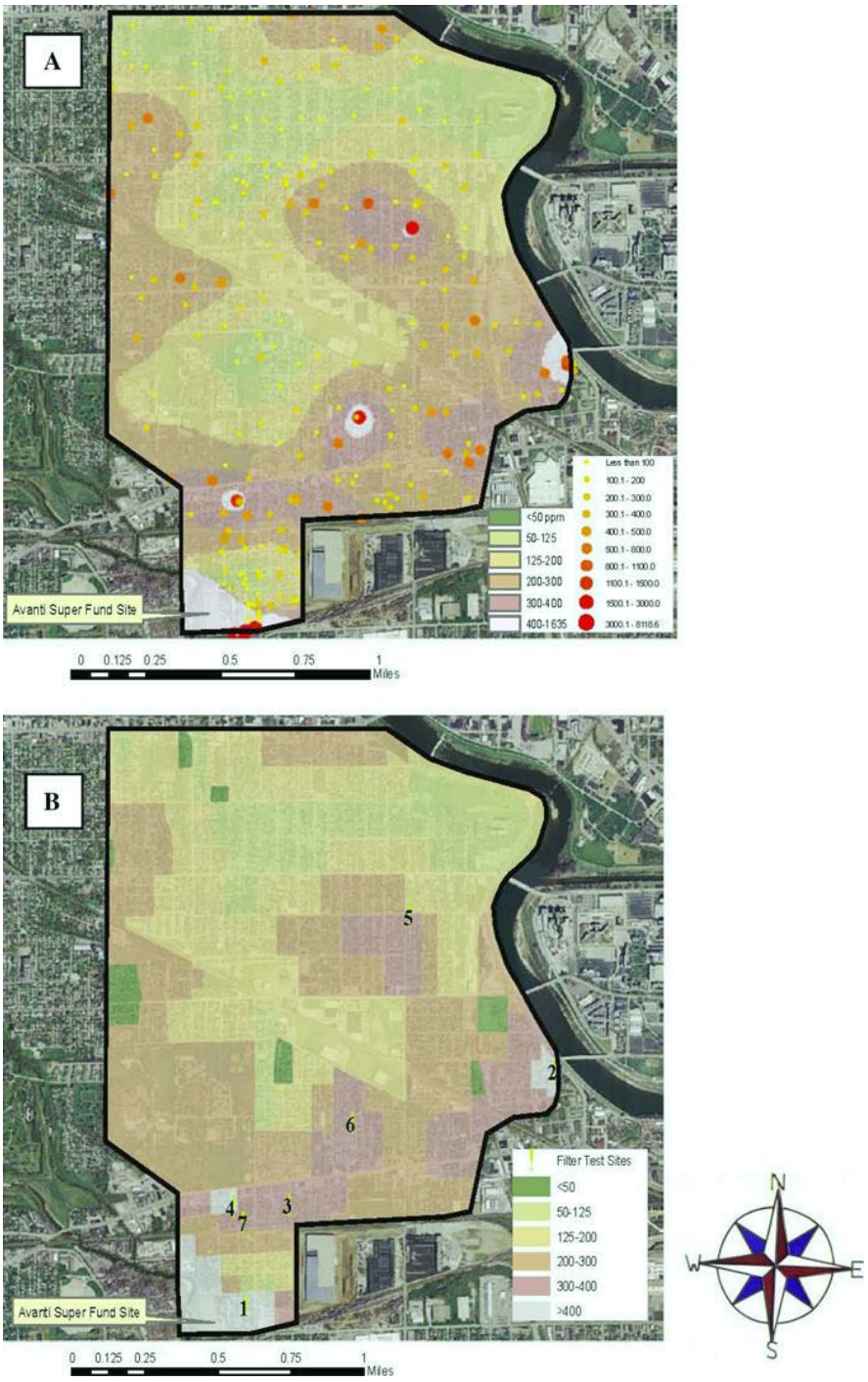

Figure 58: Inverse distance Weighted Map of WESCo Neighborhood of Indianapolis (Morrison, 2012)

5.6 Future Work

Cluster sampling should be implemented in the locations where the most enriched samples were found to aid in the interpolation of soil lead concentrations between samples. The locations of greatest interest for these clustered samples should be: Home park around Atlantic Station, East of Downtown near grant park where multiple elevated samples were found, and any of the parks that were highly enriched. In addition to the cluster samples, samples should be gathered along roadways which were used while leaded gasoline was in use. Where elevated samples are found along the old roads perpendicular transects should be collected to better understand the influence of increased distance from roadways and lead dispersion within Atlanta.

A further geochemical analysis would aid in the determination of the lead sources and which soil properties are most important in the fate of lead within the urban environment of Atlanta, Georgia. Imaging the samples which exhibited the greatest amount of enrichment with a scanning electron microscope (SEM) would aid in determining the sorption sites within the soil. The SEM images would also allow for determining if there is any mineralization of lead-bearing minerals. Isotope analysis is a costly procedure but can be crucial if confirming the source of the soil lead. Ratios of lead isotopes are unique to each ore source and can be used to interpret the age and original source of the lead. Mixing of sources throughout time can complicate this procedure and it is likely the soil lead concentrations of Atlanta are a result of multiple sources. Because of the risk of mixed sources reducing the application of isotope analysis and the high costs I would be hesitant in proceeding with the analysis without a specific need for individual site locations.

6. CONCLUSION

Even though the Environmental Protection Agency's regulations for soil lead contamination are based on the bulk soil concentration, the 100-micron fraction was used for this study because of the increased homogeneity of the sample. The fine grain fraction of the soil has also been shown to be the most mobile fraction and responsible for most exposure to the people. Since the bulk soil lead concentrations were shown not to be a strong indicator of the enrichment within the fine grain fraction, separating it was important to understanding the movement of lead throughout the urban environment.

Based on the elemental concentration data gathered from the XRF analysis of the 100-micron soil fraction there are serval conclusions which can be made about the lead concentrations within the urban environment of Atlanta, Georgia: lead enrichment is extremely heterogeneous throughout the region, enrichment is driven by anthropogenically deposited lead, and the lead is likely sourced leaded gasoline and other transportation applications. The high correlation coefficient of lead to zinc is indicative of lead sourced from the wearing of brake-pads and transportation routes which were present while leaded gas was still prevalent. The low correlation coefficient between lead and sulfur is a possible indicator of historical smelting which occurred the Atlanta urban environment.

Median lead concentrations show little variation between the various soil and bedrocks types. Many sample concentrations exceed expected natural lead concentrations for the Georgia Piedmont. Heterogeneity of concentrations is likely caused by mixing or importation of soil related to the development of the region. High-intensity urban environments also experience extensive overland wash during precipitation events because of soil compaction and placement of impermeable surfaces across the land. The overland flow can transport the

fine grain particles which sorbs the lead concentrating contaminates where flooding occurs. Sulfur is much more mobile in the environment as sulfide oxidizes to sulfate becoming mobile in surface waters not just transportation during extreme events. The differences in mobility could change the correlation between the elements. The variation in correlation coefficients across population density is indicative of the variations of lead sources responsible for the enrichment in each area. The most densely populated areas appear to have the least correlation to traffic sourced lead.

7. REFERENCES

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APPENDICES

Comparative Lead Concentrations of 100 Micron Fraction and Bulk Soil Samples

FID	100 micro Pb (ppm)	Bulk Sample Pb (ppm)
1	52	57
2	52	53
3	246	131
4	49	41
5	102	68
7	239	247
9	546	609
11	1875	697
13	139	130
15	34	130
16	271	230
17.0001	312	51
17.0002	449	39
17.0008	42	25
17.0009	94	52
28	45	26
56	44	23
57	79	63
58	26	115
59	69	18
61	111	67
63	42	20
68	156	379
69	47	50
70	75	178
71	24	34
72	36	8
73	57	101
74	75	58
75	58	38
76	133	87
77	66	117
78	69	103
82	49	29
83	90	115
84	40	95
85	49	26

86	53	25
89	60	219
90	74	52
92	84	26
93	165	63
94	96	107
95	95	80
96	124	117
97	297	29
99	47	66
100	188	180
102	75	116
104	108	63
106	180	54
107	66	46
108	10	19
109	167	140
110	188	193
111	137	40
112	59	131
113	151	58
114	50	30
115	171	282
116	464	71
117	95	47
118	54	61
119	103	37
120	79	47
121	96	186
122	66	38
123	46	52
124	73	49
125	40	68
126	119	17
127	52	71
128	71	31
129	36	98
130	168	53
131	311	94
132	148	36
133	66	13

133.2	27	41
134	101	52
135	54	41
136	125	429
137	75	36
138	61	55
139	51	57
140	237	91
141	66	9
142	111	32
143	59	46
144	22	57
145	72	52
146	74	57
148	104	245
149	378	1862
150	1542	41
152	73	153
153	204	325
154	166	29
155	67	363
156	306	170
157	434	438
158	77	72
158	110	87
159	38	39
159	82	62
160	81	87
161	155	143
162	64	52
163	42	69
164	197	170
165	32	5
166	75	43
167	81	76
168	53	11
169	74	71
170	34	38
171	59	36
172	27	25
173	186	87

174	156	234
175	206	50
176	27	64
177	50	30
179	237	212
180	69	59
181	54	2467
182	29	52
183	399	411
184	115	41
185	93	118
186	62	76
187	32	15
188	59	66
189	25	57
190	21	18
192	333	63
193	48	29
194	15	10
195	7	28
196	37	22
197	35	26
199	106	16
200	36	37
202	25	44
203	40	26
204	114	109
205	176	155
206	186	81
207	29	37
208	400	137
209	55	41
210	42	35
211	229	129
212	180	125
214	152	104
215	100	36
216	155	106
217	47	22
218	1980	243
219	907	562

220	110	82
221	82	38
222	108	79
223	52	37
224	356	27
226	86	91
226	362	1223
229	52	37
230	119	76
231	160	118
232	103	103
233	87	70
234	209	95
236	67	12
237	32	43
238	67	32
239	173	158
240	66	47
241	597	367
242	41	29
243	222	35
246	70	215
247	70	67
248	75	39
249	42	92
251	72	62
252	41	50
254	38	37
255	65	35
256	144	33
257	128	49
258	161	168
260	56	32
261	85	48
262	83	51
263	119	40
264	29	47
265	122	34
266	43	42
268	48	76
270	87	55

273	42	18
275	162	132
276	35	37
279	36	92
279	151	61
280	83	45
281	81	51
282	21	32
283	46	34
284	81	33
286	98	43
287	88	64
288	26	28
290	66	29
291	48	45
292	118	88
293	283	113
294	114	80
295	199	109
297	145	24
299	61	26
300	49	86
301	114	93
302	22	79
303	186	17
304	43	83
305	247	89
306	120	92
307	231	178
308	118	34
309	165	225
310	29	20
311	181	92
312	37	16
314	90	66
315	122	83
316	181	232
317	2461	191
318	503	111
319	63	42
320	75	56

321	84	68
322	87	65
323	111	50
324	122	117
326	116	69
327	80	141
328	81	50
329	26	18
330	41	38
331	65	59
332	159	98
333	65	65
334	153	154
335	137	81
336	83	82
337	71	57
338	68	65
339	42	138
340	179	59
341	110	80
342	71	68
343	69	56
344	112	123
345	97	17
346	47	40
347	85	83
348	64	55
350	85	81
351	15	20
352	84	82
353	39	36
355	83	61
356	59	39
357	57	40
358	60	43
359	65	412
360	52	163
361	71	48
362	119	82
363	98	28
364	80	34

365	81	50
366	169	98
367	235	141
368	25	23
369	50	63
370	48	37
371	63	42
373	75	62
374	153	137
375	57	56
376	81	55
377	70	52
378	312	186
379	157	115
381	2701	78
383	32	63
384	113	56
385	78	63
386	152	47
388	60	121
393	136	38
395	62	74
396	96	53
398	66	35
400	23	29
404	58	23
405	48	23
406	23	132
408	72	84
409	114	38
410	65	229
411	54	45
411	3029	2350
412	62	142
413	190	85
414	144	72
415	95	28
417	34	47
420	59	48
422	27	29
423	32	157

425	407	132
426	250	208
427	287	55
429	69	70
431	83	122
446	101	64
452	88	167
479	193	63
481	34	49
483	94	76
484	29	25
507	52	34
513	57	46
516	104	42
518	121	49
520	67	64
522	84	100
523	38	21
525	15	1874
526	31	20
527	33	21
528	94	72
529	50	64
530	48	40
533	55	131
560	42	54
561	201	29
586	48	42
587	61	44
649	68	49
650	666	79
680	24	81
767	175	107
789	37	131
792	40	118
851	195	1756
1096	26	363
1184	38	20
1225	24	113
1330	54	39
1333	229	81

1422	173	86
1553	167	50
1597	60	18
1598	404	200
1599	268	43
1644	52	27
1653	28	92
1654	56	127
augusta ave	457	170
HILL ST GRANT PARK	331	70

100 Micron Fraction X-ray Fluorescence Results

FID	P	P +/-	S	S +/-	Cl	Cl +/-	K	K +/-
1	<LOD	87479	<LOD	8213	<LOD	2015	14664	624
1	<LOD	73899	11068	3006	<LOD	1953	16445	675
2	<LOD	79818	10196	2960	<LOD	2058	19993	780
2	<LOD	83752	10207	2977	<LOD	2186	19476	762
3	<LOD	86292	<LOD	8466	<LOD	1821	16051	657
3	<LOD	79630	<LOD	7536	<LOD	1632	15528	641
4	<LOD	76396	<LOD	7481	<LOD	1832	16696	663
4	<LOD	74276	<LOD	6911	<LOD	1863	16550	664
4	<LOD	75322	9538	2789	<LOD	1769	16562	672
4	<LOD	68110	<LOD	6579	<LOD	1749	16195	639
5	<LOD	83806	9777	2973	<LOD	2046	19831	758
5	<LOD	83865	14532	3279	<LOD	1881	20232	767
7	<LOD	87018	9712	2982	<LOD	2041	13877	627
7	<LOD	83112	9865	2885	<LOD	2024	13361	591
8	<LOD	95791	12049	3094	<LOD	1994	16551	687
8	<LOD	94504	<LOD	7848	<LOD	2059	16859	712
9	<LOD	93952	14854	3532	<LOD	2456	16720	732
9	<LOD	95336	14576	3445	<LOD	2238	15899	704
10	<LOD	83324	12074	3225	<LOD	2248	19450	784
10	<LOD	83342	<LOD	8289	<LOD	2064	17421	699
11	<LOD	71536	12663	2914	<LOD	1686	20177	733
11	<LOD	78149	15343	3203	<LOD	1845	20204	753
12	<LOD	74819	11766	2943	<LOD	1965	12740	577
12	<LOD	89309	11332	2956	<LOD	1892	12753	587
13	<LOD	98107	12419	3385	<LOD	2386	23849	923
13	<LOD	87538	9879	3066	<LOD	2276	23158	879

15	<LOD	77583	<LOD	9203	<LOD	2375	19273	809
15	<LOD	86767	<LOD	8521	<LOD	2352	19693	801
15	<LOD	95403	<LOD	8773	<LOD	2314	20051	800
15	<LOD	90537	13403	3410	<LOD	2335	20538	837
16	<LOD	93020	8909	2865	<LOD	2187	11090	554
16	<LOD	74672	<LOD	7341	<LOD	1804	10640	519
17	<LOD	96922	13640	3499	<LOD	2333	24635	910
17	<LOD	98706	14390	3672	<LOD	2310	25764	974
17.0001	<LOD	85850	12024	3024	<LOD	2025	14488	618
17.0001	<LOD	80517	12747	3067	<LOD	1918	15340	641
17.0002	<LOD	63611	<LOD	6744	<LOD	1622	15046	604
17.0002	<LOD	71141	<LOD	6907	<LOD	1573	16522	629
17.0006	<LOD	75074	9621	2773	<LOD	1973	16888	684
17.0006	<LOD	74950	11318	2974	<LOD	2095	16378	682
17.0008	<LOD	99780	<LOD	9604	<LOD	2673	14374	697
17.0008	<LOD	102004	19101	3792	<LOD	2328	13775	658
17.0009	<LOD	85118	<LOD	8553	<LOD	1885	23360	835
17.0009	<LOD	79860	<LOD	8405	<LOD	1901	24835	870
18	<LOD	80207	<LOD	7726	<LOD	2193	19576	777
18	<LOD	87944	9592	2946	<LOD	2042	20072	773
20	<LOD	84917	13882	3379	<LOD	2323	19260	786
20	<LOD	92330	14659	3473	<LOD	2261	19916	810
21	<LOD	87102	13496	3021	<LOD	1872	9566	486
21	<LOD	92890	8821	2775	<LOD	1879	9849	513
22	<LOD	94166	12163	3408	<LOD	2532	14750	706
22	<LOD	97713	14331	3562	<LOD	2444	15394	724
23	<LOD	113316	17105	3745	<LOD	2440	17655	774
23	<LOD	106127	14430	3488	<LOD	2397	17261	752
25	<LOD	97468	12300	3287	<LOD	2384	21422	847
25	<LOD	90855	<LOD	8452	<LOD	2041	21401	839
26	<LOD	86022	<LOD	7520	<LOD	1855	13901	606
26	<LOD	70585	<LOD	7220	<LOD	1859	13175	585
27	<LOD	92436	16290	3410	<LOD	2154	15550	687
27	<LOD	89827	<LOD	8668	<LOD	2259	16026	723
28	<LOD	104153	20118	3907	<LOD	2382	17259	758
28	<LOD	105841	14088	3418	<LOD	2309	15065	694
30	<LOD	104049	<LOD	9501	<LOD	2506	20833	836
30	<LOD	93574	10631	3213	<LOD	2342	20440	799
32	<LOD	98983	<LOD	9273	<LOD	2593	23757	948
32	<LOD	95711	15412	3701	<LOD	2407	25201	976
32	<LOD	100518	15185	3708	<LOD	2370	24982	981

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446	2067	241	10282	395	79	21	1602	53
446	2218	247	9919	388	100	22	1742	56
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fy gresham	<LOD	650	9675	389	92	23	365	27
HILL ST GRANT PARK	3899	297	11945	429	63	21	665	33
HILL ST GRANT PARK	3214	276	12228	434	74	21	689	33

FID	Ca	Ca +/-	Ti	Ti +/-	Cr	Cr +/-	Mn	Mn +/-
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2	1645	236	6199	295	<LOD	56	951	38
3	14497	505	4224	233	<LOD	51	731	31
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1096	2051	232	3539	211	<LOD	49	543	27
1096	1694	212	2993	190	<LOD	40	513	25
1184	4535	255	4902	216	<LOD	40	763	29
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1225	2052	239	5704	277	<LOD	57	1294	45

1225	1969	237	6071	281	<LOD	56	1242	44
1330	11880	497	6736	333	<LOD	68	640	34
1330	13179	551	7714	365	<LOD	70	732	38
1332	10213	438	8926	362	<LOD	63	711	34
1332	9826	420	8807	347	<LOD	58	735	33
1333	10862	437	9203	352	<LOD	56	1333	46
1333	10920	444	9086	356	<LOD	58	1270	45
1422	9284	414	8102	342	<LOD	60	453	28
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1553	4592	332	10828	426	81	24	690	36
1553	4628	338	11269	440	<LOD	71	722	37
1597	1932	268	9594	400	100	24	721	36
1597	2012	279	10102	419	83	25	767	38
1598	1210	280	11660	484	<LOD	81	683	40
1598	1740	285	11137	459	<LOD	76	689	39
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1644	2122	217	1332	144	<LOD	38	356	21
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1653	1572	184	3860	195	<LOD	41	336	20
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1654	4877	260	1363	117	<LOD	31	360	19
1654	4713	259	1211	122	<LOD	34	365	20
178b	2681	252	4930	252	<LOD	51	400	25
274b	792	223	7617	322	89	20	353	25
274b	697	225	7658	329	84	20	309	24
380b	14535	518	4586	247	148	21	686	32
380b	14118	523	4339	251	129	21	680	33
410b	5481	316	8730	343	<LOD	56	944	37
418b	1667	265	10232	416	<LOD	69	588	34
480b	4523	279	4676	237	<LOD	49	434	25
482b	1211	192	5434	250	<LOD	47	299	22
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487b	2422	246	5622	272	<LOD	55	478	27
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488b	2832	266	9510	373	77	21	975	40
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489b	1229	231	7967	343	<LOD	63	1001	40
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499b	<LOD	618	8913	380	<LOD	69	768	37
499c	<LOD	635	9552	397	<LOD	67	731	36
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504b	1615	240	11564	427	88	22	1179	44
525b	<LOD	639	10120	408	82	24	637	34
525b	<LOD	684	10726	430	77	25	673	36
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91B	1952	194	2048	143	<LOD	33	261	17
91B	1742	188	5268	212	<LOD	34	238	16
91C	2089	206	2124	148	<LOD	36	275	18
91C	1796	194	2015	137	<LOD	32	244	17
augusta ave	9360	418	8664	356	<LOD	64	814	36
augusta ave	8743	408	8667	363	<LOD	65	758	35
fy gresham	<LOD	650	9675	389	92	23	365	27
HILL ST GRANT PARK	3899	297	11945	429	63	21	665	33
HILL ST GRANT PARK	3214	276	12228	434	74	21	689	33

FID	Fe	Fe +/-	Co	Co +/-	Ni	Ni +/-	Cu	Cu +/-
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1	34153	741	<LOD	271	<LOD	63	57	13
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2	39239	866	<LOD	308	<LOD	69	43	13
3	30142	646	<LOD	247	<LOD	59	<LOD	35
3	29558	631	<LOD	251	<LOD	60	51	12
4	29886	634	<LOD	245	<LOD	62	46	12
4	30218	646	<LOD	248	<LOD	63	<LOD	36
4	31254	674	<LOD	255	<LOD	63	<LOD	35
4	29462	614	<LOD	245	<LOD	59	<LOD	34
5	39943	864	<LOD	292	<LOD	63	51	12
5	41025	887	<LOD	296	<LOD	66	45	12
7	38936	864	<LOD	264	<LOD	63	52	12
7	36675	786	<LOD	264	<LOD	64	54	13
8	44496	976	<LOD	311	<LOD	70	72	14
8	46507	1044	<LOD	321	<LOD	67	60	13
9	48146	1117	<LOD	331	<LOD	71	111	15
9	48886	1124	<LOD	338	<LOD	71	125	16
10	45510	1031	<LOD	321	<LOD	70	58	13
10	43533	942	<LOD	319	<LOD	68	<LOD	36
11	24483	513	<LOD	225	<LOD	60	38	13
11	24925	536	<LOD	231	<LOD	59	39	13

12	37667	812	<LOD	274	<LOD	65	54	13
12	38356	839	<LOD	288	<LOD	66	56	13
13	51550	1207	<LOD	355	<LOD	74	<LOD	36
13	49399	1123	<LOD	360	<LOD	74	<LOD	36
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15	47900	1101	<LOD	366	<LOD	79	61	15
15	49895	1131	<LOD	344	<LOD	76	<LOD	39
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16	40650	906	<LOD	319	<LOD	71	56	14
16	36959	792	<LOD	322	<LOD	70	58	13
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17.0001	37228	800	<LOD	285	<LOD	63	53	13
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17.0002	19021	390	<LOD	184	<LOD	51	<LOD	33
17.0006	36972	802	<LOD	298	<LOD	64	38	12
17.0006	38042	838	<LOD	293	<LOD	65	<LOD	36
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32	64986	1563	<LOD	393	<LOD	77	63	14
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augusta ave	53407	1186	<LOD	353	<LOD	72	51	13
augusta ave	53970	1202	<LOD	350	<LOD	72	61	14
fy gresham	52196	1190	<LOD	352	<LOD	79	60	14
HILL ST GRANT PARK	43741	994	<LOD	333	<LOD	73	76	14
HILL ST GRANT PARK	41019	930	<LOD	349	<LOD	80	63	15

FID	Zn	Zn +/-	As	As +/-	Se	Se +/-	Rb	Rb +/-
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1	265	14	<LOD	14	<LOD	6	78	4
2	105	9	<LOD	14	<LOD	5	112	5
2	118	10	<LOD	15	<LOD	5	122	5
3	286	14	<LOD	25	<LOD	6	96	4
3	239	13	<LOD	25	<LOD	6	96	4
4	78	8	<LOD	13	<LOD	5	94	4
4	107	9	14	4	<LOD	5	103	4
4	107	9	<LOD	14	<LOD	6	96	4
4	93	9	<LOD	14	<LOD	5	106	4
5	242	13	<LOD	17	<LOD	6	88	4
5	246	13	<LOD	18	<LOD	6	83	4
7	256	13	<LOD	25	<LOD	6	77	4
7	242	13	<LOD	25	<LOD	6	71	4
8	191	12	<LOD	18	<LOD	5	108	4
8	195	12	23	6	<LOD	6	114	5
9	466	19	<LOD	38	<LOD	7	70	4
9	478	20	<LOD	39	<LOD	7	77	4
10	116	10	<LOD	14	<LOD	5	110	5
10	117	10	<LOD	15	<LOD	7	97	4
11	1228	32	<LOD	67	<LOD	10	152	5
11	1253	33	<LOD	68	<LOD	10	150	5
12	219	13	<LOD	24	<LOD	6	89	4
12	221	13	<LOD	24	<LOD	6	95	4
13	176	12	23	7	<LOD	7	110	5
13	176	12	<LOD	22	<LOD	6	117	5
15	126	11	<LOD	14	<LOD	6	114	5
15	130	11	<LOD	15	<LOD	6	121	5
15	151	11	<LOD	13	<LOD	5	120	5
15	151	11	<LOD	13	<LOD	7	126	5
16	177	12	<LOD	28	<LOD	7	73	4
16	175	12	<LOD	28	<LOD	6	78	4
17	103	10	<LOD	12	<LOD	6	121	5
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18	112	10	<LOD	14	<LOD	6	99	4
20	146	11	<LOD	14	<LOD	6	129	5
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22	107	10	<LOD	17	<LOD	6	91	4
23	103	10	<LOD	16	<LOD	6	117	5
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27	63	8	<LOD	12	<LOD	6	91	4
27	60	8	<LOD	13	<LOD	6	98	5
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37	90	9	<LOD	12	<LOD	4	76	4
38	111	10	<LOD	13	<LOD	6	111	5
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409	64	7	<LOD	17	<LOD	6	55	3
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419	251	14	<LOD	26	<LOD	7	134	5
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420	116	10	<LOD	16	<LOD	6	113	5
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421	203	62	<LOD	81	<LOD	32	107	23
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454	101	10	<LOD	16	<LOD	6	101	4
455	186	12	<LOD	20	<LOD	5	161	5
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456	218	12	<LOD	32	<LOD	6	177	6
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490	98	10	<LOD	14	<LOD	6	138	5
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497	90	9	<LOD	15	<LOD	7	83	4
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519	120	10	<LOD	16	<LOD	5	117	5
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520	94	9	<LOD	15	<LOD	6	174	6
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522	189	12	<LOD	17	<LOD	6	128	5
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523	172	13	<LOD	21	<LOD	6	132	5
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530	93	9	<LOD	14	<LOD	6	106	5
530	107	10	<LOD	15	<LOD	6	121	5
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561	246	14	<LOD	25	<LOD	6	121	5
562	170	12	<LOD	18	<LOD	6	114	5
562	155	12	<LOD	17	<LOD	6	109	5
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586	109	9	<LOD	14	<LOD	5	76	4
587	177	11	<LOD	14	<LOD	4	55	3
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1599	252	14	<LOD	28	<LOD	6	74	4
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1654	58	7	<LOD	13	<LOD	4	83	4
178b	304	15	<LOD	21	<LOD	5	111	5
274b	58	8	<LOD	14	<LOD	5	119	5

274b	58	7	<LOD	14	<LOD	5	120	5
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380b	404	17	<LOD	22	<LOD	6	50	3
410b	462	20	<LOD	32	<LOD	6	98	5
418b	156	12	<LOD	13	<LOD	5	116	5
480b	112	9	<LOD	16	<LOD	5	85	4
482b	70	8	<LOD	13	<LOD	5	75	4
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487b	174	12	<LOD	22	<LOD	6	92	4
487b	213	13	<LOD	23	<LOD	6	91	4
488b	94	9	<LOD	14	<LOD	5	94	4
488b	84	9	<LOD	13	<LOD	6	96	4
489b	143	11	<LOD	16	<LOD	6	120	5
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492b	277	15	<LOD	18	<LOD	5	119	5
494b	243	14	<LOD	15	<LOD	6	107	5
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499c	77	9	<LOD	13	<LOD	6	85	4
499c	101	10	<LOD	14	<LOD	6	83	4
504b	87	9	<LOD	14	<LOD	6	87	4
525b	90	10	<LOD	13	<LOD	6	111	5
525b	80	9	<LOD	13	<LOD	6	101	5
528b	152	11	<LOD	17	<LOD	7	157	6
528b	125	11	<LOD	18	<LOD	6	169	6
91B	163	10	<LOD	16	<LOD	5	153	5
91B	156	10	<LOD	17	<LOD	5	143	5
91C	152	10	<LOD	17	<LOD	6	145	5
91C	151	10	<LOD	16	<LOD	5	141	5
augusta ave	324	16	<LOD	34	<LOD	7	101	4
augusta ave	332	16	<LOD	35	<LOD	7	104	4
fy gresham	111	10	<LOD	15	<LOD	6	105	5
HILL ST GRANT PARK	460	19	<LOD	31	<LOD	7	78	4
HILL ST GRANT PARK	440	19	<LOD	32	<LOD	8	74	4

FID	Sr	Sr +/-	Zr	Zr +/-	Mo	Mo +/-	Ag	Ag +/-
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1	96	4	506	12	<LOD	13	<LOD	44
2	50	3	646	14	<LOD	13	<LOD	44
2	47	3	688	15	<LOD	14	<LOD	45
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767	72	4	533	12	15	4	<LOD	45
767	66	4	541	12	<LOD	13	<LOD	44
789	82	4	518	12	<LOD	13	<LOD	43
789	80	4	555	12	<LOD	13	<LOD	44
792	30	3	371	10	<LOD	13	<LOD	45
792	32	3	371	10	<LOD	13	<LOD	46
851	39	3	556	13	<LOD	13	<LOD	45
851	40	3	563	13	<LOD	13	<LOD	45
900	45	3	681	14	<LOD	13	<LOD	42
900	45	3	678	14	<LOD	12	<LOD	42
999	94	5	1002	20	<LOD	15	<LOD	47
999	91	5	1023	21	<LOD	15	<LOD	47
1096	51	3	238	8	<LOD	12	<LOD	42

1096	55	3	238	8	<LOD	12	<LOD	42
1184	44	3	549	11	<LOD	12	<LOD	41
1184	50	3	555	12	<LOD	12	<LOD	41
1225	45	3	543	12	<LOD	13	<LOD	44
1225	41	3	537	12	<LOD	13	<LOD	43
1330	164	6	292	9	<LOD	13	<LOD	46
1330	172	6	298	9	<LOD	13	<LOD	45
1332	90	4	744	15	<LOD	13	<LOD	43
1332	86	4	732	15	<LOD	13	<LOD	44
1333	66	3	766	15	<LOD	13	<LOD	43
1333	71	4	814	16	<LOD	14	<LOD	44
1422	73	4	674	14	<LOD	13	<LOD	44
1422	63	3	694	14	<LOD	13	<LOD	43
1553	55	3	824	17	<LOD	14	<LOD	44
1553	51	3	844	17	<LOD	14	<LOD	46
1597	33	3	833	18	<LOD	15	<LOD	48
1597	39	3	793	17	<LOD	14	<LOD	47
1598	30	3	565	14	<LOD	14	<LOD	48
1598	24	3	544	13	<LOD	14	<LOD	47
1599	50	3	665	14	<LOD	13	<LOD	45
1599	49	3	651	14	<LOD	13	<LOD	44
1644	36	3	178	6	<LOD	11	<LOD	41
1644	32	3	190	7	<LOD	11	<LOD	42
1653	22	2	459	10	<LOD	12	<LOD	41
1653	19	2	461	10	<LOD	12	<LOD	41
1654	51	3	202	7	<LOD	11	<LOD	39
1654	44	3	205	7	<LOD	11	<LOD	40
178b	45	3	408	10	<LOD	13	<LOD	44
274b	60	3	853	16	<LOD	13	<LOD	43
274b	57	3	871	16	<LOD	13	<LOD	43
380b	95	4	397	10	<LOD	13	<LOD	45
380b	97	4	406	10	<LOD	13	<LOD	44
410b	61	4	1039	20	<LOD	15	<LOD	46
418b	40	3	453	11	<LOD	13	<LOD	46
480b	52	3	375	9	<LOD	12	<LOD	42
482b	42	3	953	18	<LOD	13	<LOD	43
482b	35	3	931	17	<LOD	13	<LOD	42
487b	63	3	839	16	<LOD	13	<LOD	43
487b	69	4	841	16	<LOD	13	<LOD	44
488b	22	3	666	14	<LOD	14	<LOD	45
488b	26	3	663	14	<LOD	13	<LOD	45

489b	49	3	337	10	<LOD	13	<LOD	45
490b	29	3	383	10	<LOD	13	<LOD	45
492b	27	3	360	10	<LOD	13	<LOD	45
494b	32	3	633	14	<LOD	13	<LOD	45
499b	17	2	533	12	<LOD	13	<LOD	44
499c	15	2	549	13	<LOD	13	<LOD	45
499c	16	2	558	13	<LOD	13	<LOD	46
504b	30	3	790	16	<LOD	13	<LOD	45
525b	25	3	521	13	<LOD	14	<LOD	47
525b	26	3	527	13	<LOD	14	<LOD	47
528b	61	4	612	14	<LOD	13	<LOD	45
528b	70	4	613	14	<LOD	14	<LOD	46
91B	40	3	256	7	<LOD	11	<LOD	40
91B	42	3	298	8	<LOD	11	<LOD	41
91C	45	3	328	9	<LOD	12	<LOD	42
91C	38	3	327	8	<LOD	11	<LOD	41
augusta ave	76	4	707	15	<LOD	13	<LOD	44
augusta ave	71	4	708	15	<LOD	14	<LOD	45
fy gresham	33	3	645	14	<LOD	14	<LOD	45
HILL ST GRANT PARK	40	3	1496	27	<LOD	15	<LOD	45
HILL ST GRANT PARK	41	3	1771	32	<LOD	17	<LOD	48

FID	Cd	Cd +/-	Sn	Sn +/-	Sb	Sb +/-	I	I +/-
1	<LOD	53	<LOD	86	<LOD	93	<LOD	599
1	<LOD	56	<LOD	90	<LOD	98	<LOD	596
2	<LOD	56	<LOD	90	<LOD	99	<LOD	588
2	<LOD	59	<LOD	95	<LOD	103	<LOD	590
3	<LOD	55	<LOD	88	<LOD	97	<LOD	598
3	<LOD	55	<LOD	89	<LOD	97	<LOD	590
4	<LOD	54	<LOD	89	<LOD	97	<LOD	566
4	<LOD	56	<LOD	90	<LOD	99	<LOD	540
4	<LOD	56	<LOD	90	<LOD	98	<LOD	557
4	<LOD	55	<LOD	89	<LOD	96	<LOD	519
5	<LOD	54	<LOD	87	<LOD	95	<LOD	616
5	<LOD	54	<LOD	87	<LOD	95	<LOD	612
7	<LOD	53	<LOD	86	<LOD	95	<LOD	623
7	<LOD	54	<LOD	88	<LOD	96	<LOD	596
8	<LOD	55	<LOD	87	<LOD	93	<LOD	614
8	<LOD	56	<LOD	88	<LOD	96	<LOD	629
9	<LOD	57	<LOD	92	<LOD	102	<LOD	669

9	<LOD	59	<LOD	96	<LOD	105	<LOD	682
10	<LOD	58	<LOD	93	<LOD	100	<LOD	646
10	<LOD	58	<LOD	92	<LOD	100	<LOD	606
11	<LOD	55	<LOD	90	<LOD	98	<LOD	490
11	<LOD	57	<LOD	91	<LOD	101	<LOD	498
12	<LOD	55	<LOD	88	<LOD	95	<LOD	579
12	<LOD	56	<LOD	91	<LOD	100	<LOD	583
13	63	19	<LOD	95	<LOD	104	<LOD	656
13	<LOD	59	<LOD	94	<LOD	103	<LOD	637
15	<LOD	59	<LOD	94	<LOD	104	<LOD	682
15	<LOD	62	<LOD	101	<LOD	110	<LOD	650
15	<LOD	59	<LOD	95	<LOD	104	<LOD	671
15	<LOD	58	<LOD	96	<LOD	104	<LOD	689
16	<LOD	57	<LOD	93	<LOD	102	<LOD	620
16	<LOD	57	<LOD	93	<LOD	101	<LOD	587
17	<LOD	60	<LOD	95	<LOD	104	<LOD	700
17	<LOD	58	<LOD	94	<LOD	103	<LOD	723
17.0001	<LOD	55	<LOD	88	<LOD	96	<LOD	609
17.0001	<LOD	54	<LOD	87	<LOD	95	<LOD	628
17.0002	<LOD	53	<LOD	86	<LOD	94	<LOD	456
17.0002	54	17	<LOD	85	<LOD	93	<LOD	448
17.0006	<LOD	54	<LOD	86	<LOD	94	<LOD	548
17.0006	<LOD	55	<LOD	87	<LOD	95	<LOD	569
17.0008	<LOD	56	<LOD	89	<LOD	97	<LOD	830
17.0008	72	19	<LOD	94	<LOD	102	<LOD	779
17.0009	<LOD	55	<LOD	89	<LOD	97	<LOD	554
17.0009	<LOD	55	<LOD	88	<LOD	96	<LOD	578
18	<LOD	56	<LOD	90	<LOD	98	<LOD	591
18	<LOD	57	<LOD	92	<LOD	100	<LOD	550
20	<LOD	57	<LOD	93	<LOD	101	<LOD	646
20	<LOD	58	<LOD	93	<LOD	102	<LOD	666
21	<LOD	55	<LOD	89	<LOD	96	<LOD	572
21	<LOD	54	<LOD	88	<LOD	96	<LOD	605
22	<LOD	59	<LOD	95	<LOD	104	<LOD	748
22	<LOD	60	<LOD	97	<LOD	105	<LOD	734
23	<LOD	58	<LOD	95	<LOD	104	<LOD	733
23	<LOD	58	<LOD	93	<LOD	102	<LOD	728
25	<LOD	59	<LOD	95	<LOD	104	<LOD	605
25	<LOD	56	<LOD	91	<LOD	100	<LOD	593
26	<LOD	55	<LOD	88	<LOD	98	<LOD	542
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28	<LOD	58	<LOD	93	<LOD	103	<LOD	681
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32	<LOD	59	<LOD	96	<LOD	105	<LOD	662
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38	<LOD	58	<LOD	94	<LOD	104	<LOD	702
38	<LOD	60	<LOD	96	<LOD	105	<LOD	732
39	<LOD	55	<LOD	89	<LOD	97	<LOD	639
39	<LOD	58	<LOD	93	<LOD	101	<LOD	662
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40	<LOD	55	<LOD	88	<LOD	95	<LOD	593
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118	<LOD	55	<LOD	91	<LOD	98	<LOD	628
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FID	Ba	Ba +/-	Hg	Hg +/-	Pb	Pb +/-
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8	342	51	<LOD	15	98	8
8	376	53	<LOD	15	84	7
9	446	59	<LOD	19	527	18
9	526	61	<LOD	19	565	19
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10	401	52	<LOD	14	47	6
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12	383	51	<LOD	16	206	10
12	503	54	<LOD	14	212	11
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487	320	50	<LOD	16	172	10
487	352	51	<LOD	17	179	10
488	435	62	<LOD	16	26	6
488	373	61	<LOD	16	31	6
489	423	59	<LOD	16	62	7
489	353	59	<LOD	15	65	7
490	370	61	<LOD	16	39	6
490	391	58	<LOD	16	40	6
492	371	58	<LOD	17	94	8
492	385	60	<LOD	15	99	8
493	370	55	<LOD	18	74	7
493	362	56	<LOD	17	64	7
494	389	57	<LOD	14	39	6
494	367	60	<LOD	16	38	6
496	447	57	<LOD	15	42	6
496	310	52	<LOD	15	51	6
497	510	66	<LOD	17	48	6
497	463	62	<LOD	12	53	7
498	438	59	<LOD	14	44	6
498	404	58	<LOD	15	27	5
499	412	66	<LOD	16	38	6
499	425	62	<LOD	16	33	6
500	366	64	<LOD	16	34	6
500	451	69	<LOD	18	43	6
501	265	53	<LOD	16	144	9
501	402	55	<LOD	17	141	9

502	432	55	<LOD	15	39	6
502	389	56	<LOD	15	25	5
503	334	54	<LOD	16	27	5
503	276	55	<LOD	15	31	6
504	475	64	<LOD	15	40	6
504	331	59	<LOD	16	36	6
505	357	60	<LOD	17	50	7
505	327	58	<LOD	17	49	7
506	325	61	<LOD	15	62	7
506	395	63	<LOD	16	76	8
507	298	53	<LOD	15	64	7
507	345	53	<LOD	17	61	7
508	440	55	<LOD	15	71	7
508	363	53	<LOD	15	60	7
509	361	55	<LOD	16	17	5
509	341	56	<LOD	14	23	5
510	458	70	<LOD	17	45	7
510	431	69	<LOD	15	39	6
511	321	51	<LOD	14	27	5
511	288	49	<LOD	16	35	6
512	319	60	<LOD	18	36	6
512	525	61	<LOD	16	40	6
513	368	54	<LOD	17	49	6
513	309	52	<LOD	14	64	7
514	322	50	<LOD	14	35	5
514	336	50	<LOD	17	47	6
515	405	61	<LOD	15	30	6
515	391	57	<LOD	16	32	6
516	279	50	<LOD	12	38	6
516	291	50	<LOD	18	35	6
517	366	56	<LOD	16	45	6
517	334	54	<LOD	13	40	6
518	667	72	<LOD	16	57	7
518	551	70	<LOD	16	49	7
519	384	60	<LOD	16	70	7
519	422	60	<LOD	18	64	7
520	303	47	<LOD	14	73	7
520	230	45	<LOD	15	60	6
521	261	45	<LOD	13	56	6
521	320	48	<LOD	15	51	6
522	360	52	<LOD	16	79	7

522	303	50	<LOD	17	89	8
523	445	68	<LOD	18	129	9
523	490	72	<LOD	18	107	9
524	320	46	<LOD	14	38	6
524	288	45	<LOD	13	43	6
525	398	69	<LOD	17	<LOD	16
525	560	70	<LOD	16	25	6
526	313	53	<LOD	14	37	6
526	245	50	<LOD	15	24	5
527	554	76	<LOD	16	26	6
527	566	71	<LOD	18	40	6
528	170	46	<LOD	13	<LOD	13
528	259	48	<LOD	13	<LOD	13
528	456	57	<LOD	17	89	8
528	552	58	<LOD	18	99	8
529	396	54	<LOD	14	51	6
529	368	51	<LOD	18	48	6
530	541	57	<LOD	14	43	6
530	641	58	<LOD	13	53	6
531	513	49	<LOD	15	126	9
531	521	52	<LOD	16	121	9
532	560	56	<LOD	17	64	7
532	561	58	<LOD	15	78	7
533	292	45	<LOD	14	58	6
533	307	45	<LOD	15	52	6
560	466	74	<LOD	17	43	7
560	518	72	<LOD	19	41	7
561	415	65	<LOD	15	206	11
561	426	66	<LOD	17	196	11
562	593	73	<LOD	18	75	8
562	450	70	<LOD	16	78	8
586	223	38	<LOD	14	43	6
586	218	40	<LOD	14	52	6
587	254	37	<LOD	14	63	6
587	200	36	<LOD	12	61	6
649	237	40	<LOD	15	98	7
649	251	38	<LOD	16	99	7
650	385	49	<LOD	16	652	20
650	323	49	<LOD	15	679	20
680	385	56	<LOD	16	43	6
680	397	57	<LOD	14	38	6

688	343	59	<LOD	14	32	6
688	386	60	<LOD	17	56	7
719	383	49	<LOD	16	98	8
719	309	48	<LOD	15	106	8
767	360	50	<LOD	16	182	10
767	382	50	<LOD	18	168	10
789	278	48	<LOD	15	56	6
789	403	54	<LOD	15	58	6
792	591	74	<LOD	17	34	6
792	715	73	<LOD	16	46	6
851	444	61	<LOD	16	196	11
851	467	60	<LOD	18	193	11
900	274	49	<LOD	16	170	9
900	324	47	<LOD	15	156	9
999	658	65	<LOD	29	3986	76
999	656	64	<LOD	29	4094	78
1096	269	41	<LOD	15	52	6
1096	266	38	<LOD	12	49	6
1184	207	37	<LOD	15	51	6
1184	157	37	<LOD	12	59	6
1225	363	51	<LOD	12	23	5
1225	276	49	<LOD	15	25	5
1330	561	62	<LOD	15	57	7
1330	449	64	<LOD	15	51	7
1332	423	60	<LOD	17	274	12
1332	330	56	<LOD	17	290	13
1333	285	54	<LOD	17	219	11
1333	344	56	<LOD	16	238	12
1422	440	58	<LOD	16	171	10
1422	371	56	<LOD	15	175	10
1553	400	66	<LOD	16	164	10
1553	442	68	<LOD	17	169	10
1597	507	66	<LOD	17	60	7
1597	502	68	<LOD	16	60	7
1598	520	77	<LOD	18	397	16
1598	524	74	<LOD	19	411	16
1599	483	63	<LOD	17	271	12
1599	479	62	<LOD	17	264	12
1644	286	33	<LOD	15	39	5
1644	295	32	<LOD	13	39	5
1653	154	35	<LOD	11	28	5

1653	<LOD	104	<LOD	13	27	5
1654	74	23	<LOD	12	61	6
1654	163	27	<LOD	12	51	6
178b	286	46	<LOD	13	140	9
274b	390	54	<LOD	14	39	6
274b	391	55	<LOD	15	58	6
380b	257	46	<LOD	17	154	9
380b	285	48	<LOD	16	154	9
410b	371	55	<LOD	16	341	14
418b	383	65	<LOD	16	34	6
480b	292	44	<LOD	16	72	7
482b	243	44	<LOD	13	32	5
482b	372	46	<LOD	15	20	5
487b	318	49	<LOD	17	185	10
487b	290	51	<LOD	16	181	10
488b	331	58	<LOD	14	34	6
488b	455	61	<LOD	17	33	6
489b	420	58	<LOD	16	70	7
490b	484	67	<LOD	17	48	6
492b	387	58	<LOD	17	95	8
494b	393	59	<LOD	17	60	7
499b	464	64	<LOD	16	33	6
499c	430	64	<LOD	17	30	6
499c	481	64	<LOD	14	36	6
504b	491	65	<LOD	13	43	6
525b	499	66	<LOD	17	28	6
525b	480	68	<LOD	18	29	6
528b	469	56	<LOD	16	87	8
528b	505	59	<LOD	17	87	8
91B	164	28	<LOD	12	107	7
91B	114	34	<LOD	15	90	7
91C	130	29	<LOD	13	102	7
91C	<LOD	78	<LOD	13	95	7
augusta ave	412	59	<LOD	17	446	16
augusta ave	533	62	<LOD	18	467	16
fy gresham	454	63	<LOD	17	57	7
HILL ST GRANT PARK	325	62	<LOD	16	329	14
HILL ST GRANT PARK	345	62	<LOD	20	333	15

Sample Soil, Bedrock, Population, Density, Distance to Road

Sample ID	Fine_Pb	Bulk_Pb	Soil ID	USDA KEY	Census Tract	Lat	Long	Bedrock	NPU #	2015 Population	Population Density Clusters	Land Use
100	188	180	6	659148	Census Tract 85	+33.7758562	-084.4443269	biotite gneiss	9	11889	3	Developed-Open Space
102	75	116	6	659148	Census Tract 85	+33.7758562	-084.4443269	biotite gneiss	9	11889	3	Developed-Low Intensity
104	108	63	1	659150	Census Tract 86.01	+33.7814512	-084.4661915	biotite gneiss	7	8778	2	Developed-Open Space
106	180	54	1	659150	Census Tract 87	+33.7938339	-084.4598776	granite	7	8778	2	Developed-Open Space
107	66	46	1	659150	Census Tract 87	+33.7938339	-084.4598776	granite	7	8778	2	Developed-Medium Intensity
108	10	19	1	659150	Census Tract 87	+33.7938339	-084.4598776	biotite gneiss	7	8778	2	Developed-Low Intensity
109	167	140	1	659150	Census Tract 87	+33.7938339	-084.4598776	granite	7	8778	2	Developed-Low Intensity
11	1875	697	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	17	16280	5	Developed-Low Intensity
110	188	193	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	granite	3	18122	3	Developed-Medium Intensity
111	137	40	6	659148	Census Tract 93	+33.8212723	-084.3808773	granite	2	47292	4	Developed-Open Space
112	159	131	6	659148	Census Tract 93	+33.8212723	-084.3808773	granite	2	47292	4	Developed-Open Space
113	151	58	6	659148	Census Tract 93	+33.8212723	-084.3808773	granite	2	47292	4	Developed-Low Intensity
114	50	30	6	659148	Census Tract 91.01	+33.8093237	-084.3950330	granite	3	18122	3	Developed-Low Intensity
115	171	282	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Open Space
116	464	71	6	659148	Census Tract 91.01	+33.8093237	-084.3950330	biotite gneiss	5	42121	6	Developed-Low Intensity
117	95	47	6	659148	Census Tract 91.02	+33.8067606	-084.3865964	biotite gneiss	5	42121	6	Developed-Low Intensity
13	139	130	6	659148	Census Tract 58	+33.7318610	-084.4105985	mica schist	18	14198	4	Developed-Open Space
135	54	41	6	659148	Census Tract 52	+33.7355106	-084.3544774	mica schist	19	19286	3	Developed-Low Intensity
136	125	429	6	659148	Census Tract 52	+33.7355106	-084.3544774	mica schist	19	19286	3	Developed-Low Intensity
137	75	36	1	659150	Census Tract 69	+33.7183138	-084.3587699	biotite gneiss	19	19286	3	Developed-Low Intensity
138	61	55	6	659148	Census Tract 69	+33.7183138	-084.3587699	mica schist	19	19286	3	Developed-Open Space
139	51	57	1	659150	Census Tract 69	+33.7183138	-084.3587699	mica schist	19	19286	3	Developed-Open Space
140	237	91	6	659148	Census Tract 64	+33.7188154	-084.3735791	mica schist	21	11111	3	Developed-Medium Intensity
141	66	9	6	659148	Census Tract 69	+33.7183138	-084.3587699	mica schist	19	19286	3	Developed-High Intensity
142	111	32	6	659148	Census Tract 41	+33.7408497	-084.4280690	biotite gneiss	17	16280	5	Developed-Low Intensity
143	59	46	6	659148	Census Tract 19	+33.7661963	-084.3872629	biotite gneiss	12	26886	5	Developed-Medium Intensity
144	22	57	6	659148	Census Tract 21	+33.7655130	-084.3947157	biotite gneiss	12	26886	5	Developed-High Intensity
145	72	52	6	659148	Census Tract 10.02	+33.7763538	-084.3995123	biotite gneiss	5	42121	6	Developed-Medium Intensity
146	74	57	6	659148	Census Tract 10.02	+33.7763538	-084.3995123	biotite gneiss	5	42121	6	Developed-Medium Intensity
148	104	245	6	659148	Census Tract 10.01	+33.7828223	-084.3902405	biotite gneiss	5	42121	6	Developed-Open Space
149	378	1862	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Low Intensity
15	34	130	6	659148	Census Tract 62	+33.7284830	-084.4217305	mica schist	17	16280	5	Developed-Medium Intensity
150	1542	41	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Low Intensity
152	73	153	6	659148	Census Tract 6	+33.7853862	-084.4056539	biotite gneiss	5	42121	6	Developed-Low Intensity

Sample ID	Fine_Pb	Bulk_Pb	Soil ID	USDA KEY	Census Tract	Lat	Long	Bedrock	NPU #	2015 Population	Population Density Clusters	Land Use
153	204	325	6	659148	Census Tract 10.01	+33.7828223	-084.3902405	biotite gneiss	5	42121	6	Developed-Medium Intensity
154	166	29	6	659148	Census Tract 6	+33.7853862	-084.4056539	biotite gneiss	5	42121	6	Developed-Medium Intensity
155	67	363	6	659148	Census Tract 6	+33.7853862	-084.4056539	biotite gneiss	5	42121	6	Developed-High Intensity
156	306	170	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Open Space
156	306	170	6	659148	Census Tract 6	+33.7853862	-084.4056539	biotite gneiss	5	42121	6	Developed-Medium Intensity
157	434	438	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Low Intensity
158	77	72	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Medium Intensity
159	38	39	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Open Space
16	271	230	6	659148	Census Tract 42	+33.7390423	-084.4181855	mica schist	17	16280	5	Developed-Low Intensity
160	81	87	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Medium Intensity
161	155	143	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-High Intensity
162	64	52	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Low Intensity
163	43	69	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Medium Intensity
164	197	170	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-Medium Intensity
165	32	5	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	4	10690	2	Developed-High Intensity
166	75	43	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-High Intensity
167	81	76	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Open Space
168	53	11	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Medium Intensity
169	74	71	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Deciduous Forest
170	34	38	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Open Space
171	59	26	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Open Space
172	27	25	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Low Intensity
173	186	87	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Low Intensity
174	156	234	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Low Intensity
175	206	50	2	659149	Census Tract 88	+33.8123521	-084.4590717	mica schist	4	10690	2	Developed-Low Intensity
176	27	64	2	659149	Census Tract 87	+33.7938339	-084.4598776	mica schist	7	8778	2	Developed-Medium Intensity
177	50	30	2	659149	Census Tract 87	+33.7938339	-084.4598776	mica schist	7	8778	2	Developed-Medium Intensity
179	237	212	1	659150	Census Tract 86.02	+33.7928898	-084.4901297	granite	7	8778	2	Developed-Low Intensity
18	52	24	6	659148	Census Tract 48	+33.7443311	-084.3839375	mica schist	19	19286	3	Developed-Low Intensity
180	69	59	1	659150	Census Tract 86.02	+33.7928898	-084.4901297	granite	7	8778	2	Developed-Low Intensity
181	54	2467	1	659150	Census Tract 86.02	+33.7928898	-084.4901297	biotite gneiss	7	8778	2	Developed-Low Intensity
182	52	29	1	659150	Census Tract 86.02	+33.7928898	-084.4901297	biotite gneiss	7	8778	2	Developed-Open Space
183	399	411	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Low Intensity
184	115	41	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Open Space

Sample ID	Fine_Pb	Bulk_Pb	Soil ID	USDA KEY	Census Tract	Lat	Long	Bedrock	NPU #	2015 Population	Population Density Clusters	Land Use
185	93	118	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Open Space
186	62	76	1	659150	Census Tract 88	+33.8123521	-084.4590717	granite	4	10690	2	Developed-Low Intensity
2	52	53	6	659148	Census Tract 119	+33.7538839	-084.3825135	mica schist	12	26886	5	Developed-High Intensity
205	176	155	6	659148	Census Tract 12.01	+33.7763742	-084.3803049	biotite gneiss	5	42121	6	Developed-Low Intensity
206	186	81	6	659148	Census Tract 12.01	+33.7763742	-084.3803049	biotite gneiss	5	42121	6	Developed-Open Space
207	29	37	6	659148	Census Tract 13	+33.7761933	-084.3715699	biotite gneiss	5	42121	6	Developed-Low Intensity
208	400	137	6	659148	Census Tract 13	+33.7761933	-084.3715699	biotite gneiss	5	42121	6	Developed-Medium Intensity
209	55	41	6	659148	Census Tract 14	+33.7770784	-084.3622634	biotite gneiss	6	23530	4	Developed-Medium Intensity
210	42	35	1	659150	Census Tract 14	+33.7770784	-084.3622634	biotite gneiss	6	23530	4	Developed-Open Space
211	229	129	1	659150	Census Tract 15	+33.7764970	-084.3539007	mica schist	6	23530	4	Developed-Low Intensity
212	180	125	1	659150	Census Tract 15	+33.7764970	-084.3539007	mica schist	6	23530	4	Developed-Low Intensity
214	152	104	6	659148	Census Tract 16	+33.7669390	-084.3570136	mica schist	13	17385	4	Developed-Open Space
215	100	36	6	659148	Census Tract 120	+33.7361403	-084.3928230	mica schist	18	14198	4	Developed-Low Intensity
216	155	106	6	659148	Census Tract 120	+33.7361403	-084.3928230	mica schist	18	14198	4	Developed-Medium Intensity
217	47	22	6	659148	Census Tract 120	+33.7361403	-084.3928230	mica schist	18	14198	4	Developed-High Intensity
218	1980	243	6	659148	Census Tract 55.01	+33.7298670	-084.3837371	mica schist	18	14198	4	Developed-High Intensity
219	907	562	6	659148	Census Tract 48	+33.7443311	-084.3839375	mica schist	18	14198	4	Developed-Medium Intensity
220	110	82	6	659148	Census Tract 18	+33.7663445	-084.3780718	mica schist	12	26886	5	Developed-Medium Intensity
221	82	38	6	659148	Census Tract 18	+33.7663445	-084.3780718	mica schist	12	26886	5	Developed-Low Intensity
222	108	79	6	659148	Census Tract 28	+33.7580870	-084.3793990	mica schist	12	26886	5	Developed-Medium Intensity
223	52	37	6	659148	Census Tract 28	+33.7580870	-084.3793990	mica schist	12	26886	5	Developed-Medium Intensity
224	356	27	6	659148	Census Tract 29	+33.7580053	-084.3693491	mica schist	12	26886	5	Developed-Low Intensity
226	362	1223	6	659148	Census Tract 119	+33.7538839	-084.3825135	mica schist	12	26886	5	Developed-Medium Intensity
227	86	91	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
229	52	37	1	659150	Census Tract 206	+33.7576172	-084.3356822	mica schist	14	13806	3	Developed-Low Intensity
230	119	76	1	659150	Census Tract 204	+33.7660727	-084.3443392	mica schist	13	17385	4	Developed-Medium Intensity
231	160	118	1	659150	Census Tract 204	+33.7660727	-084.3443392	mica schist	13	17385	4	Developed-Low Intensity
232	103	103	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
233	87	70	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
234	209	95	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Low Intensity
236	67	12	1	659150	Census Tract 92	+33.8122786	-084.3618468	biotite gneiss	6	23530	4	Developed-Low Intensity
237	32	43	1	659150	Census Tract 94.02	+33.8221523	-084.3642584	biotite gneiss	2	47292	4	Developed-Medium Intensity
238	67	32	1	659150	Census Tract 92	+33.8122786	-084.3618468	biotite gneiss	6	23530	4	Developed-Open Space
239	173	158	1	659150	Census Tract 2	+33.7916329	-084.3641988	biotite gneiss	6	23530	4	Developed-Medium Intensity

Sample ID	Fine_Pb	Bulk_Pb	Soil ID	USDA KEY	Census Tract	Lat	Long	Bedrock	NPU #	2015 Population	Population Density Clusters	Land Use
24	60	34	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	10	9399	3	Developed-Low Intensity
240	60	47	1	659150	Census Tract 2	+33.7916329	-084.3641988	biotite gneiss	6	23530	4	Deciduous Forest
241	597	367	6	659148	Census Tract 50	+33.7420805	-084.3650954	mica schist	19	19286	3	Developed-Medium Intensity
242	41	29	6	659148	Census Tract 41	+33.7408497	-084.4280690	biotite gneiss	17	16280	5	Developed-Low Intensity
243	222	35	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	17	16280	5	Developed-Low Intensity
246	215	70	1	659150	Census Tract 81.02	+33.7418287	-084.4716010	biotite gneiss	8	21208	2	Developed-Low Intensity
247	70	67	1	659150	Census Tract 81.02	+33.7418287	-084.4716010	biotite gneiss	8	21208	2	Developed-Low Intensity
248	75	39	1	659150	Census Tract 81.02	+33.7418287	-084.4716010	biotite gneiss	8	21208	2	Developed-Low Intensity
251	72	62	1	659150	Census Tract 81.02	+33.7418287	-084.4716010	biotite gneiss	8	21208	2	Developed-Medium Intensity
252	41	50	1	659150	Census Tract 81.02	+33.7418287	-084.4716010	biotite gneiss	8	21208	2	Developed-Open Space
254	38	37	1	659150	Census Tract 79	+33.7322732	-084.4910511	biotite gneiss	8	21208	2	Developed-Open Space
255	65	35	3	659082	Census Tract 79	+33.7322732	-084.4910511	biotite gneiss	8	21208	2	Developed-Open Space
256	144	33	3	659082	Census Tract 77.04	+33.7080796	-084.4873952	biotite gneiss	8	21208	2	Developed-Open Space
257	128	49	3	659082	Census Tract 77.04	+33.7080796	-084.4873952	biotite gneiss	8	21208	2	Developed-Open Space
258	161	168	3	659082	Census Tract 77.04	+33.7080796	-084.4873952	biotite gneiss	8	21208	2	Mixed Forest
260	56	32	3	659082	Census Tract 77.04	+33.7080796	-084.4873952	granite	15	16490	3	Developed-Low Intensity
261	85	48	3	659082	Census Tract 77.04	+33.7080796	-084.4873952	granite	15	16490	3	Developed-Open Space
28	45	26	6	659148	Census Tract 61	+33.7277552	-084.4370324	mica schist	16	10063	2	Developed-Low Intensity
282	32	21	6	659148	Census Tract 74	+33.6789102	-084.4070935	gneiss	20	12398	3	Developed-Low Intensity
283	46	34	6	659148	Census Tract 74	+33.6789102	-084.4070935	granitic gneiss	20	12398	3	Developed-Open Space
284	81	33	6	659148	Census Tract 70.01	+33.6915165	-084.3868055	granitic gneiss	22	18050	2	Developed-Low Intensity
286	98	43	6	659148	Census Tract 70.01	+33.6915165	-084.3868055	granitic gneiss	21	11111	3	Developed-Open Space
287	88	64	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Developed-Low Intensity
288	26	28	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Deciduous Forest
290	60	29	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Developed-Open Space
291	118	88	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Developed-Open Space
291	48	45	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Deciduous Forest
293	283	113	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Developed-Medium Intensity
294	114	80	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Developed-Low Intensity
295	199	109	6	659148	Census Tract 65	+33.7141012	-084.4101267	mica schist	20	12398	3	Developed-Low Intensity
297	145	24	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	17	16280	5	Developed-Low Intensity
299	91	26	6	659148	Census Tract 42	+33.7390423	-084.4181855	biotite gneiss	17	16280	5	Developed-Low Intensity
3	246	131	6	659148	Census Tract 119	+33.7538839	-084.3825135	mica schist	12	26886	5	Developed-High Intensity
300	49	86	6	659148	Census Tract 24	+33.7586698	-084.4248089	biotite gneiss	10	9399	3	Developed-Low Intensity

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301	114	93	6	659148	Census Tract 24	+33.7586698	-084.4248089	biotite gneiss	10	9399	3	Developed-Low Intensity
302	79	22	6	659148	Census Tract 38	+33.7508286	-084.4120230	biotite gneiss	17	16280	5	Developed-Low Intensity
303	186	17	6	659148	Census Tract 44	+33.7407585	-084.4017770	mica schist	18	14198	4	Developed-Medium Intensity
304	43	83	6	659148	Census Tract 44	+33.7407585	-084.4017770	mica schist	18	14198	4	Developed-Low Intensity
305	247	89	6	659148	Census Tract 120	+33.7361403	-084.3928230	mica schist	18	14198	4	Developed-Medium Intensity
306	120	92	6	659148	Census Tract 57	+33.7319561	-084.4032660	mica schist	18	14198	4	Developed-Open Space
307	231	178	6	659148	Census Tract 57	+33.7319561	-084.4032660	mica schist	18	14198	4	Developed-Open Space
308	118	34	6	659148	Census Tract 55.02	+33.7162175	-084.3867651	granitic gneiss	21	11111	3	Developed-Medium Intensity
309	165	225	6	659148	Census Tract 55.02	+33.7162175	-084.3867651	granitic gneiss	21	11111	3	Developed-Open Space
310	29	20	6	659148	Census Tract 55.02	+33.7162175	-084.3867651	granitic gneiss	21	11111	3	Developed-Medium Intensity
311	181	92	6	659148	Census Tract 55.02	+33.7162175	-084.3867651	granitic gneiss	21	11111	3	Developed-Low Intensity
312	37	16	6	659148	Census Tract 55.02	+33.7162175	-084.3867651	granitic gneiss	21	11111	3	Developed-Low Intensity
314	90	66	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	22	18050	2	Developed-Low Intensity
315	122	83	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	22	18050	2	Developed-Medium Intensity
316	181	232	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	17	16280	5	Developed-Low Intensity
317	2461	191	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	17	16280	5	Developed-Low Intensity
318	503	111	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	17	16280	5	Developed-Medium Intensity
319	63	42	6	659148	Census Tract 84	+33.7618564	-084.4355748	biotite gneiss	9	11889	3	Developed-Low Intensity
320	75	56	6	659148	Census Tract 84	+33.7618564	-084.4355748	biotite gneiss	9	11889	3	Developed-Low Intensity
321	84	68	6	659148	Census Tract 24	+33.7586698	-084.4248089	biotite gneiss	10	9399	3	Developed-Open Space
322	87	65	6	659148	Census Tract 24	+33.7586698	-084.4248089	biotite gneiss	10	9399	3	Developed-Low Intensity
323	111	50	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
324	122	117	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
326	116	69	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
329	26	18	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
330	40	38	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
331	65	59	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
332	159	98	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
333	65	65	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
334	153	154	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
335	137	81	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
336	83	82	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Low Intensity
337	71	57	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
338	68	65	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space

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339	42	138	6	659148	Census Tract 4	+33.7883241	-084.3785105	biotite gneiss	5	42121	6	Developed-Open Space
340	179	59	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
341	110	80	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
342	71	68	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
343	69	56	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
344	112	123	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
345	97	17	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
346	47	40	6	659148	Census Tract 5	+33.7961417	-084.3854516	biotite gneiss	5	42121	6	Developed-Open Space
347	85	83	1	659150	Census Tract 1	+33.7997992	-084.3549254	biotite gneiss	6	23530	4	Developed-Open Space
348	64	55	1	659150	Census Tract 1	+33.7997992	-084.3549254	biotite gneiss	6	23530	4	Developed-Open Space
350	85	81	1	659150	Census Tract 1	+33.7997992	-084.3549254	biotite gneiss	6	23530	4	Developed-Open Space
352	84	82	1	659150	Census Tract 1	+33.7997992	-084.3549254	biotite gneiss	6	23530	4	Developed-Open Space
353	39	36	1	659150	Census Tract 2	+33.7916329	-084.3641988	biotite gneiss	6	23530	4	Developed-Open Space
355	83	61	1	659150	Census Tract 1	+33.7997992	-084.3549254	biotite gneiss	6	23530	4	Developed-Low Intensity
357	57	40	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
360	52	163	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
360	52	163	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
361	71	48	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
362	119	82	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
363	98	28	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
364	80	34	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
365	81	50	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
366	169	98	1	659150	Census Tract 202	+33.7755415	-084.3401025	mica schist	13	17385	4	Developed-Open Space
370	48	37	1	659150	Census Tract 209	+33.7365000	-084.3368889	biotite gneiss	19	19286	3	Developed-Open Space
371	63	42	1	659150	Census Tract 209	+33.7365000	-084.3368889	biotite gneiss	19	19286	3	Deciduous Forest
373	75	62	1	659150	Census Tract 209	+33.7365000	-084.3368889	biotite gneiss	19	19286	3	Developed-Open Space
374	153	137	1	659150	Census Tract 209	+33.7365000	-084.3368889	biotite gneiss	19	19286	3	Developed-Open Space
375	57	56	1	659150	Census Tract 209	+33.7365000	-084.3368889	biotite gneiss	19	19286	3	Deciduous Forest
376	81	55	1	659150	Census Tract 209	+33.7365000	-084.3368889	mica schist	19	19286	3	Developed-Low Intensity
377	70	52	1	659150	Census Tract 209	+33.7365000	-084.3368889	mica schist	19	19286	3	Developed-Low Intensity
378	312	186	1	659150	Census Tract 209	+33.7365000	-084.3368889	mica schist	19	19286	3	Developed-Low Intensity
379	157	115	1	659150	Census Tract 209	+33.7365000	-084.3368889	mica schist	19	19286	3	Developed-Low Intensity
381	2701	78	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	5	42121	6	Developed-Open Space
383	32	63	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	biotite gneiss	5	42121	6	Developed-Open Space

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384	113	56	6	659148	Census Tract 89.02	+33.7984651	-084.4194299	granite	4	10690	2	Developed-Low Intensity
394	66	35	6	659148	Census Tract 60	+33.7379611	-084.4390857	biotite gneiss	17	16280	5	Developed-Open Space
4	49	41	6	659148	Census Tract 119	+33.7538839	-084.3825135	mica schist	12	26886	5	Developed-Medium Intensity
403	58	23	6	659148	Census Tract 53	+33.7321404	-084.3708875	granitic gneiss	19	19286	3	Developed-Low Intensity
412	190	85	1	659150	Census Tract 100.02	+33.8680492	-084.3577716	mica schist	2	47292	4	Evergreen Forest
413	144	72	1	659150	Census Tract 100.02	+33.8680492	-084.3577716	mica schist	2	47292	4	Evergreen Forest
414	95	28	1	659150	Census Tract 71	+33.6963573	-084.3546554	gneiss	22	18050	2	Developed-Low Intensity
416	34	47	1	659150	Census Tract 71	+33.6963573	-084.3546554	biotite gneiss	19	19286	3	Deciduous Forest
422	32	157	6	659148	Census Tract 31	+33.7520808	-084.3530446	mica schist	13	17385	4	Developed-Low Intensity
425	407	132	1	659150	Census Tract 208.02	+33.7469390	-084.3020683	mica schist	14	13806	3	Developed-Low Intensity
426	250	208	1	659150	Census Tract 208.02	+33.7469390	-084.3020683	mica schist	14	13806	3	Developed-Open Space
427	287	55	1	659150	Census Tract 208.02	+33.7469390	-084.3020683	mica schist	14	13806	3	Developed-Low Intensity
429	69	70	1	659150	Census Tract 208.02	+33.7469390	-084.3020683	mica schist	14	13806	3	Developed-Open Space
446	101	64	6	659148	Census Tract 52	+33.7355106	-084.3544774	mica schist	19	19286	3	Developed-Open Space
452	88	167	6	659148	Census Tract 69	+33.7183138	-084.3587699	mica schist	19	19286	3	Developed-Low Intensity
479	193	63	6	659148	Census Tract 7	+33.7799333	-084.4233152	biotite gneiss	10	9399	3	Developed-Open Space
482	94	76	6	659148	Census Tract 53	+33.7321404	-084.3708875	mica schist	19	19286	3	Developed-Low Intensity
483	29	25	6	659148	Census Tract 53	+33.7321404	-084.3708875	mica schist	19	19286	3	Evergreen Forest
5	102	68	6	659148	Census Tract 119	+33.7538839	-084.3825135	mica schist	12	26886	5	Developed-High Intensity
51	15	20	1	659150	Census Tract 1	+33.7997992	-084.3549254	biotite gneiss	6	23530	4	Developed-Low Intensity
533	55	131	1	659150	Census Tract 92	+33.8122786	-084.3618468	biotite gneiss	6	23530	4	Developed-Medium Intensity
61	111	67	6	659148	Census Tract 30	+33.7587580	-084.3572779	mica schist	13	17385	4	Developed-Open Space
63	42	20	6	659148	Census Tract 55.01	+33.7298670	-084.3837371	granitic gneiss	18	14198	4	Developed-Medium Intensity
68	156	379	6	659148	Census Tract 67	+33.7021727	-084.3954527	granitic gneiss	21	11111	3	Developed-Low Intensity
69	47	50	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	22	18050	2	Developed-Low Intensity
7	239	247	6	659148	Census Tract 38	+33.7508286	-084.4120230	mica schist	17	16280	5	Developed-Low Intensity
70	75	178	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	22	18050	2	Developed-Low Intensity
71	24	34	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	22	18050	2	Deciduous Forest
72	36	8	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	22	18050	2	Developed-Low Intensity
73	57	101	1	659150	Census Tract 70.02	+33.6920865	-084.3682107	granitic gneiss	21	11111	3	Developed-Open Space
74	75	58	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	10	9399	3	Developed-Low Intensity
75	58	38	6	659148	Census Tract 40	+33.7499759	-084.4361794	biotite gneiss	10	9399	3	Developed-Low Intensity
76	133	87	6	659148	Census Tract 83.02	+33.7573898	-084.4522860	biotite gneiss	9	11889	3	Developed-Low Intensity
77	66	117	6	659148	Census Tract 83.02	+33.7573898	-084.4522860	biotite gneiss	9	11889	3	Developed-Open Space

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78	103	69	1	659150	Census Tract 83.01	+33.7642260	-084.4588619	biotite gneiss	9	11889	3	Developed-Low Intensity
82	49	29	1	659150	Census Tract 83.01	+33.7642260	-084.4588619	biotite gneiss	9	11889	3	Developed-Open Space
83	90	115	1	659150	Census Tract 86.01	+33.7814512	-084.4661915	biotite gneiss	9	11889	3	Developed-Low Intensity
84	40	95	1	659150	Census Tract 86.01	+33.7814512	-084.4661915	biotite gneiss	9	11889	3	Developed-Low Intensity
85	49	26	1	659150	Census Tract 86.01	+33.7814512	-084.4661915	biotite gneiss	9	11889	3	Developed-Open Space
86	53	25	6	659148	Census Tract 85	+33.7758562	-084.4443269	biotite gneiss	9	11889	3	Developed-Low Intensity
89	219	60	1	659150	Census Tract 78.07	+33.7624507	-084.4968617	biotite gneiss	8	21208	2	Developed-Open Space
9	546	609	6	659148	Census Tract 42	+33.7390423	-084.4181855	mica schist	17	16280	5	Developed-Medium Intensity
90	74	52	1	659150	Census Tract 82.01	+33.7699904	-084.4826839	biotite gneiss	8	21208	2	Developed-Low Intensity
92	84	26	6	659148	Census Tract 23	+33.7672174	-084.4186028	biotite gneiss	10	9399	3	Developed-Low Intensity
93	165	63	6	659148	Census Tract 23	+33.7672174	-084.4186028	biotite gneiss	11	6148	4	Developed-Medium Intensity
94	96	107	6	659148	Census Tract 85	+33.7758562	-084.4443269	biotite gneiss	10	9399	3	Developed-Low Intensity
95	95	80	6	659148	Census Tract 23	+33.7672174	-084.4186028	biotite gneiss	10	9399	3	Developed-Low Intensity
96	124	117	6	659148	Census Tract 7	+33.7799333	-084.4233152	biotite gneiss	10	9399	3	Developed-Medium Intensity
97	297	29	6	659148	Census Tract 7	+33.7799333	-084.4233152	biotite gneiss	10	9399	3	Developed-Low Intensity
99	47	66	6	659148	Census Tract 87	+33.7938339	-084.4598776	biotite gneiss	7	8778	2	Developed-Low Intensity
J40	38	NA	1	659150	Census Tract 100.01	+33.8625134	-084.3754032	mica schist	2	47292	4	Developed-Open Space
J41	125	NA	1	659150	Census Tract 100.01	+33.8625134	-084.3754032	mica schist	2	47292	4	Developed-Open Space
J42	14	NA	1	659150	Census Tract 100.01	+33.8625134	-084.3754032	mica schist	2	47292	4	Deciduous Forest
J43	40	NA	1	659150	Census Tract 100.01	+33.8625134	-084.3754032	mica schist	2	47292	4	Developed-Open Space
J44	20	NA	1	659150	Census Tract 100.01	+33.8625134	-084.3754032	mica schist	2	47292	4	Developed-Open Space
M1	23	NA	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	mica schist	3	18122	3	Developed-Open Space
M10	32	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space
M18	37	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Open Space
M19	1677	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-High Intensity
M2	30	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Open Space
M20	103	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Low Intensity
M21	63	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Open Space
M22	162	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Open Space
M23	139	NA	6	659148	Census Tract 91.01	+33.8093237	-084.3950330	granite	3	18122	3	Developed-Open Space
M25	137	NA	6	659148	Census Tract 90	+33.8141290	-084.4108285	mica schist	3	18122	3	Developed-Open Space
M26	72	NA	1	659150	Census Tract 95.01	+33.8308250	-084.3962959	granite	3	18122	3	Developed-Low Intensity
M27	36	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Open Space
M28	53	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space

Sample ID	Fine_Pb	Bulk_Pb	Soil ID	USDA KEY	Census Tract	Lat	Long	Bedrock	NPU #	2015 Population	Population Density Clusters	Land Use
M29	32	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Evergreen Forest
M3	53	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Open Space
M30	0	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space
M31	62	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space
M32	81	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space
M33	25	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Low Intensity
M34	47	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Deciduous Forest
M35	97	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Low Intensity
M36	39	NA	1	659150	Census Tract 99	+33.8613359	-084.3918503	mica schist	1	11691	1	Developed-Open Space
M37	32	NA	1	659150	Census Tract 99	+33.8613359	-084.3918503	mica schist	1	11691	1	Developed-Low Intensity
M38	60	NA	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	mica schist	3	18122	3	Developed-Open Space
M39	224	NA	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	granite	2	47292	4	Developed-Open Space
M4	266	NA	6	659148	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Open Space
M40	38	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Open Space
M41	120	NA	1	659150	Census Tract 99	+33.8613359	-084.3918503	mica schist	3	18122	3	Developed-Low Intensity
M42	14	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M43	40	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	mica schist	1	11691	1	Developed-Medium Intensity
M44	20	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Open Space
M45	32	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Low Intensity
M46	51	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Low Intensity
M47	127	NA	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	mica schist	3	18122	3	Developed-Open Space
M5	195	NA	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	granite	3	18122	3	Developed-Open Space
M52	80	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M54	108	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	mica schist	1	11691	1	Developed-Open Space
M55	79	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	mica schist	1	11691	1	Developed-Open Space
M56	118	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M57	71	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M58	52	NA	6	659148	Census Tract 95.01	+33.8308250	-084.3962959	mica schist	3	18122	3	Developed-Low Intensity
M59	39	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Evergreen Forest
M6	62	NA	6	659148	Census Tract 98.01	+33.8391503	-084.4145464	granite	3	18122	3	Developed-Open Space
M60	56	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Low Intensity
M61	71	NA	1	659150	Census Tract 98.01	+33.8391503	-084.4145464	mica schist	1	11691	1	Developed-Open Space
M62	79	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M63	49	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M64	33	NA	1	659150	Census Tract 98.02	+33.8636555	-084.4250506	mica schist	1	11691	1	Developed-Open Space
M7	16	NA	2	659149	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space
M8	19	NA	2	659149	Census Tract 98.02	+33.8636555	-084.4250506	biotite gneiss	1	11691	1	Developed-Open Space
M9	29	NA	1	659150	Census Tract 90	+33.8141290	-084.4108285	granite	3	18122	3	Developed-Low Intensity

ICP-MS Results

Analyte Symbol	B	Li	Na	Mg	Al	K	Ca	Cd	V	Cr	Mn	Fe	Hf	Ni	Er
Unit Symbol	ppm	ppm	%	%	%	%	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
Detection Limit	20	0.5	0.01	0.01	0.01	0.01	0.01	0.1	1	1	1	0.01	0.1	0.5	0.1
174	< 20	22.6	1.77	0.13	8.07	2.55	0.44	0.2	15	17	691	0.98	0.8	7.5	4.5
78	< 20	24.1	0.09	0.42	2.47	1.45	0.18	< 0.1	52	23	384	3.89	2.4	11.1	1.6
181	< 20	35.8	0.54	0.64	8.12	2.15	0.51	0.1	23	51	754	4.08	1.8	30.5	2
102	< 20	22.9	0.23	0.18	8.47	2.91	0.23	0.2	39	36	501	2.92	2.9	16.2	2.5
270	< 20	16.6	0.21	0.23	8.18	1.52	0.2	0.1	75	70	550	3.82	3.1	27.8	1.9
296	< 20	6.6	0.37	0.14	2.49	0.55	0.4	< 0.1	6	33	381	1.91	0.3	9.2	1.8
52	< 20	35.1	0.13	0.61	> 10.0	1.91	0.36	0.1	94	35	696	6.39	3.3	28.4	3.4
122	< 20	42.3	0.23	0.72	> 10.0	1.68	0.47	0.2	52	42	638	5.6	0.9	41.1	3.3
34	30	12.6	0.32	0.25	3.91	1.64	0.33	0.1	37	31	257	1.67	< 0.1	10.8	1.2
360	30	24.6	0.45	0.82	5.63	1.65	1.22	0.5	76	89	1230	4.69	1.5	49.8	2.2
11	30	32.7	0.15	0.25	7.15	1.84	0.33	4	45	33	459	2.31	0.6	15.1	2.2
1096	< 20	27.9	0.14	0.44	6.01	2.27	0.31	< 0.1	47	15	475	2.66	2.3	10.3	1.5
9	< 20	19.4	0.29	0.38	7.11	1.28	0.49	1.4	37	72	849	4.5	0.9	40.8	2.5
183	< 20	20.5	0.11	0.13	5.47	2.21	0.33	1	24	30	232	1.26	2.5	10.2	0.8
226	< 20	25.9	0.29	0.68	> 10.0	2.22	0.43	0.3	99	85	894	4.99	1.1	47.2	2
379	< 20	23.1	0.14	0.2	7.73	1.41	0.16	0.2	57	58	520	4.16	3.1	38.7	1.9
268	< 20	30.9	0.22	0.6	0.95	2.09	0.31	0.1	143	63	1270	6.5	2.7	62.6	2.7
309	< 20	32.5	0.39	0.72	8.1	2.19	0.5	0.5	40	58	883	6.57	0.7	57.5	3.9
219	40	27.7	0.23	0.67	6.92	1.46	0.77	2	64	85	864	4.46	0.4	42.1	1.9
525	50	29.6	0.1	0.31	5.03	1.03	0.1	< 0.1	177	99	816	5.83	2.2	46.6	0.9

Analyte Symbol	Be	Ho	Hg	Ag	Cs	Co	Eu	Bi	Se	Zn	Ga	As	Rb	Y	Zr
Unit Symbol	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.1	0.1	10	0.05	0.05	0.1	0.05	0.02	0.1	0.2	0.1	0.1	0.2	0.1	1
174	4.2	1.6	50	0.21	6.27	2.4	0.3	0.81	1	119	23.9	1.2	425	50.3	21
78	1.8	0.5	60	< 0.05	4.47	11.9	0.59	0.19	0.6	56	19.9	0.7	82.9	13.4	73
181	2.2	0.8	< 10	< 0.05	4.33	16.2	1.33	0.23	0.4	173	18.4	< 0.1	138	19	61
102	1.4	0.9	< 10	< 0.05	4.82	9.6	1.21	0.17	0.7	137	18.5	0.4	167	20.9	94
270	1.3	0.9	< 10	< 0.05	2.41	9.3	1.45	0.2	1.2	116	19.5	< 0.1	88.7	23	99
296	0.7	0.9	10	< 0.05	0.64	3.8	1.33	0.08	0.4	33.5	6.4	< 0.1	24.1	23.2	9
52	2.4	1.3	20	< 0.05	5.34	28	2.77	0.17	1	120	21	< 0.1	125	28.9	106
122	2.7	1.3	60	< 0.05	4.52	25.2	1.99	0.21	0.7	164	21.9	< 0.1	120	29.3	30
34	1	0.5	180	0.16	1.76	4.7	1.01	0.17	0.5	43	10.1	< 0.1	73.1	13.1	8
360	2.1	0.9	50	< 0.05	2.88	19.5	1.62	0.38	0.7	162	13.7	< 0.1	65.5	19.5	50
11	2.1	0.8	170	0.25	4.08	8	1.05	0.67	1.3	1320	16.2	2.1	143	20.6	46
1096	2.2	0.6	40	< 0.05	2.57	9.2	1.01	0.11	0.6	120	19.5	< 0.1	137	14.5	76
9	1.5	1	100	0.2	2.23	18.3	1.93	0.35	0.7	441	15.2	< 0.1	72.6	24.2	28
183	1.6	0.3	< 10	0.31	3.94	3.5	0.34	0.7	1	497	11.3	4.3	182	7.3	75
226	1.9	0.8	< 10	0.27	3.65	21	1.29	0.43	0.9	179	19.8	0.9	103	16.3	36
379	1.4	0.8	< 10	< 0.05	4.19	9.5	1.99	0.33	1	163	18.7	< 0.1	96.1	17.4	102
268	2.3	1.2	< 10	< 0.05	3.67	31.1	2.05	0.32	1.2	100	24.9	< 0.1	116	26.7	91
309	2.1	1.8	80	0.14	2.55	26.6	3.37	0.19	0.7	273	20.6	< 0.1	123	40.8	23
219	1.9	0.9	290	0.65	2.34	18.9	1.91	0.53	0.8	882	17.7	4.4	92.4	22.1	22
525	1.4	0.3	60	0.15	3.41	21.9	0.43	0.23	0.7	80.5	19.4	1.6	24.5	4.7	72

Analyte Symbol	Nb	Mo	In	Sn	Sb	Te	Ba	La	Ce	Pr	Nd	Sm	Gd	Tb	Dy
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.1	0.05	0.1	1	0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
174	12.4	0.89	< 0.1	4	0.4	< 0.1	140	10.9	19.7	2.8	11.8	4.1	6.2	1.2	8.1
78	1.4	0.3	< 0.1	2	0.2	< 0.1	330	15.3	36.4	3.8	15.7	2.8	2.9	0.4	2.6
181	< 0.1	0.06	< 0.1	< 1	< 0.1	< 0.1	574	61.7	115	11.9	48	7.7	6.6	0.8	4.2
102	0.2	0.14	< 0.1	< 1	< 0.1	< 0.1	801	32.9	84.7	7.9	33.3	6.7	5.7	0.8	4.5
270	6.1	0.6	< 0.1	1	0.3	< 0.1	381	87.1	166	18.2	75.2	14.1	11.8	1.4	6.4
296	< 0.1	< 0.05	< 0.1	< 1	< 0.1	< 0.1	189	105	204	23.5	92.5	15.8	13.6	1.5	6.9
52	0.6	0.36	< 0.1	3	< 0.1	< 0.1	648	83.2	157	18.2	76.2	12.6	10.1	1.3	7.3
122	< 0.1	0.05	< 0.1	< 1	< 0.1	< 0.1	352	59.7	118	13.5	57.2	10.2	9.3	1.2	6.8
34	0.3	0.41	< 0.1	1	< 0.1	< 0.1	505	48.3	98.2	10.7	44.1	7.6	6.4	0.7	3.4
360	4.5	0.6	< 0.1	2	< 0.1	< 0.1	435	42.4	93.1	11.1	48	8.9	8.2	1.1	5.3
11	2.7	1.1	0.1	4	0.7	< 0.1	814	47.2	103	10.3	42.8	7.7	6.5	0.8	4.5
1096	3.9	0.66	< 0.1	3	0.3	< 0.1	519	36.4	82.3	8.2	32.9	5.6	4.5	0.6	2.9
9	< 0.1	< 0.05	< 0.1	3	< 0.1	< 0.1	462	62.7	107	13.8	58.3	10.6	8.8	1.1	5.7
183	6.1	1.55	< 0.1	6	2	< 0.1	286	13.7	28.7	2.8	11	2.1	1.8	0.2	1.3
226	18.9	1.29	< 0.1	9	1.1	< 0.1	481	29.7	77.4	7.8	33.1	6.2	5.7	0.8	4.2
379	0.4	0.35	< 0.1	4	0.3	< 0.1	402	86.7	130	16.8	65.4	11.2	8.3	1	4.9
268	8.8	1.96	< 0.1	2	< 0.1	0.1	520	84	174	18.9	77.1	14.3	12.1	1.4	7
309	< 0.1	0.07	< 0.1	2	< 0.1	< 0.1	563	134	253	30.5	120	21.6	18.2	2.2	10.9
219	0.1	0.39	< 0.1	2	< 0.1	< 0.1	634	68.7	133	14.7	62	11.1	9.6	1.1	5.5
525	17.8	0.9	< 0.1	4	0.3	< 0.1	219	5.2	15.1	2	9.6	2	2	0.3	1.8

Analyte Symbol	Cu	Ge	Tm	Yb	Lu	Ta	Sr	W	Re	Tl	Pb	Th	U
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.001	0.05	0.5	0.1	0.1
174	20	< 0.1	0.7	4.5	0.6	0.7	47.2	0.5	< 0.001	2.84	147	18.5	11.2
78	29.3	0.2	0.2	1.7	0.3	< 0.1	19.2	< 0.1	< 0.001	0.51	33.9	9.6	3.5
181	51.7	< 0.1	0.3	1.7	0.2	< 0.1	76.5	< 0.1	< 0.001	0.77	57.6	20.1	5.4
102	27	< 0.1	0.4	2.4	0.3	< 0.1	103	< 0.1	< 0.001	0.89	70.7	11.1	5.2
270	45.1	< 0.1	0.2	1.4	0.2	0.1	34.6	< 0.1	< 0.001	0.53	85.3	31.1	7.1
296	22.1	< 0.1	0.2	1.2	0.2	< 0.1	53.5	< 0.1	< 0.001	0.14	15.7	34.1	8.1
52	52.4	< 0.1	0.5	3.1	0.4	< 0.1	116	< 0.1	< 0.001	0.79	56.8	12.4	4.3
122	57.3	< 0.1	0.4	3	0.4	< 0.1	34.3	< 0.1	< 0.001	0.73	73.4	16.5	3.8
34	15.8	< 0.1	0.1	0.9	0.1	< 0.1	57.7	< 0.1	< 0.001	0.39	44.6	18.8	3.4
360	56.5	< 0.1	0.3	1.8	0.2	0.2	68.2	0.1	< 0.001	0.64	55.3	15.2	2.8
11	45.2	< 0.1	0.3	2.1	0.3	0.2	64.2	0.3	< 0.001	1.28	1940	23.6	8.1
1096	37.8	< 0.1	0.2	1.4	0.2	0.2	42.9	0.5	< 0.001	0.7	60	12	2.9
9	137	< 0.1	0.3	2.2	0.3	< 0.1	49.8	< 0.1	< 0.001	0.55	534	16.2	3.2
183	33.6	< 0.1	0.1	0.8	0.1	0.4	43.1	1	< 0.001	1.04	385	12	4.1
226	121	0.2	0.3	1.8	0.2	1.2	51.5	1.5	< 0.001	0.78	91.6	11.7	3.3
379	76.1	< 0.1	0.3	1.8	0.2	< 0.1	45.5	< 0.1	< 0.001	0.65	151	17.8	5.5
268	106	< 0.1	0.3	2.2	0.3	0.1	40	< 0.1	< 0.001	0.86	47.9	27.5	7.7
309	76.8	< 0.1	0.5	2.7	0.4	< 0.1	54.1	< 0.1	< 0.001	0.64	138	40.6	6.6
219	116	< 0.1	0.2	1.5	0.2	< 0.1	102	< 0.1	< 0.001	0.63	871	20	4.1
525	50.4	1.1	0.1	0.9	0.1	1.3	15	1.1	< 0.001	0.62	33	3.1	2